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THE EFFECTS OF SMOKING MARIHUANA ON PHYSICAL PERFORMANCE

by



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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL EDUCATION

EDMONTON, Alberta

FALL, 1971

ABSTRACT

The purpose of the present investigation was to determine the effects marihuana had on physical performance as determined by the eight variables; heart rate, blood pressure, muscular strength, physical work capacity, forced vital capacity, flow rate of expiration, sensitivity threshold, and complex coordination. The results were analyzed by the analysis of variance and Newman-Keuls comparison between ordered means.

Twenty volunteer human marihuana smokers took part in three experimental testing sessions. Each subject reported to a laboratory on three different days to be tested. Day one was used as their control testing sessions. Day two and three were the placebo and marihuana sessions. On day two the subjects smoked either placebo or marihuana and completed the test battery. On day three the subject smoked marihuana if he had placebo on day two, and vice versa.

The results indicated that there was a significant difference between the marihuana treatment group and the other treatment groups in heart rate, systolic and diastolic blood pressure and in their physical work capacity. On the other hand no significant difference was exhibited as a result of smoking marihuana in muscular strength, forced vital capacity or expired flow rate from the lungs. Also, marihuana had no significant effect on the subject's sensitivity threshold of index finger in the dominant hand or the non-dominant hand. Finally, marihuana had no significant effect

on complex coordination over a period of four timed trials.

ACKNOWLEDGEMENTS

Sincere thanks and gratitude are extended to Dr. Mohan Singh the thesis chairman and to Dr. Brian Sproule and Dr. R. Wilberg for their assistance, guidance and encouragement.

Special acknowledgement is extended to Dr. Howard Wenger who gave his time and assistance unselfishly throughout the study, to the Government of Canada, Department of National Health and Welfare, who supplied the cannabis sativa plant material for the purpose of this study, to the Medical Research Council who supplied the Grant to conduct the investigation and to the two medical doctors who gave their valuable time in the testing of the subjects.

Also, thanks to my wife Laura who gave up a great deal of her time and patience unselfishly in the completion of the thesis.

Finally, to the eighteen subjects, who endured the two long months of participation in the testing of the study, your loyalty was sincerely appreciated. Thank you.

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CHAPTER I

STATEMENT OF THE PROBLEM

INTRODUCTION

There is increasing evidence available that the smoking of marihuana is becoming more and more popular among university students throughout the North American continent. The writer, through personal contact with his students has discovered that there is a widespread belief among students that the smoking of marihuana improves an athlete's performance on the playfield. The proposed research project was designed to study this problem.

Not much is known about the physiological effects of smoking marihuana on humans. The President's Commission of Law Enforcement and the Administration of Justice described the present state of knowledge by concluding that ".....no careful and detailed analysis of the American experience, (with marihuana) seems to have been attempted. Basic research has been almost non-existent " (89). Two recent studies conducted by Weil, et al (98) and Isbell, et al (50) throw some light on the effects of marihuana on man. Isbell et al (50) reported that marihuana had no significant effect on pupil size, rate of respiration, systolic and diastolic blood pressure, or on the threshold level of elicitation of knee jerk. He also found that resting pulse rate was elevated and that the effects depend upon the dosage administered. Weil, et al (98) showed that marihuana naive individuals demonstrated impaired performance on simple intel-

lectual and psychomotor skills, after smoking marihuana. He found the impairment dose related. He also stated that it increased heart rate moderately, although no change occurred in rate of respiration, pupil size or blood sugar levels.

The review of the current state of research concerning the effects of marihuana has led to the obvious conclusion that very little is known about the effects of this drug on human performance. The controversy over the effects of marihuana has increased the necessity of obtaining some objective data regarding the effects which marihuana has on the student population. According to Isbell, et al, "the chief advantage of assays in humans is of course that the subjective effects of such drugs can be assessed only in man. Since the mental effects of substances found in hashish and marihuana are of paramount interest, assays of these materials in man is, sense, more specific than the dog. ..." (50). Weil, et al, as a result of their research have reported that, "it is possible and safe to study the effects of marihuana on human volunteers who smoke it in a laboratory " (98).

THE PROBLEM

The principle aim and purpose of the study was to determine the effects marihuana has on human performance as determined and measured by heart rate, blood pressure, muscular strength, physical work capacity, forced vital capa-

city, flow rate of expiration, sensitivity threshold, MVO_2 and complex muscular coordination. Subjects underwent each of these tests by the double-blind method on three different days under the following conditions:

1. without smoking placebo or marihuana
2. after smoking marihuana
3. after smoking placebo

The results were analyzed to determine the effects of smoking marihuana on each of the tests administered. An analysis of variance was run on each variable with Newman-Keuls Comparison between ordered means applied to the significant "F" ratios.

The following hypotheses were tested at the 0.05 level:

1. No significant change in heart rate takes place as a result of smoking marihuana.
2. No significant difference in blood pressure, (systolic and diastolic), occurs as a result of smoking marihuana.
3. No significant change occurs for muscular grip strength in the dominant or nondominant hand as a result of smoking marihuana.
4. No significant change occurs in physical work capacity or MVO_2 as a result of smoking marihuana.
5. No significant change occurs in the forced vital capacity after smoking marihuana.
6. No significant changes occur in expired flow rate as a result of smoking marihuana.

7. No significant difference occurs in the sensitivity threshold of the dominant or nondominant index finger after smoking marihuana.
8. No significant change occurs in complex muscular coordination over time after smoking marihuana.

LIMITATIONS

1. In view of the primary state of knowledge about marihuana, it is difficult to predict which psychological tests will be sensitive to the effects of the drug. The tests chosen were selected because, in addition to being likely to demonstrate effects, they have been used to evaluate many other psychoactive drugs.
2. Set and setting will be difficult to control. Set refers to the subject's psychological expectations and personality structure. The total environment in which the drug is taken is the setting.
3. Medical, social, ethical and legal concerns about the welfare of the subjects are a major problem in a project of this kind. When can subjects safely be sent home from the laboratory? What kind of follow-up care, if any, should be taken (98)

DELIMITATIONS

1. The study was limited to twenty volunteer marihuana smokers.
2. The marihuana was smoked rather than taken orally because this is the way nearly all people use marihuana.

Standardization of dose is not assured by giving the drug orally because little is known about gastrointestinal absorption of the highly water insoluble cannabinoids in man. Also, there is less detoxification by smoking because of not passing directly through the liver via the portal veins and possible conversion of tetrahydrocannabinol to a more active substance by the heart. Also, there is considerable indirect evidence from users that the quality of intoxication is different when marijuana or preparations of it are ingested rather than smoked. Dosage is uniform by smoking. Marijuana smokers are accustomed to a rapid onset of action due to efficient absorption (98).

3. The marijuana was of a high dosage in content of the tetrahydrocannabinol (THC) resin.
4. The study was limited to a certain number of physiological and psychological measures.
5. The variance between subjects is significant, pointing out the importance of using each subject as his own control in an assay (50).

DEFINITION OF TERMS

Addiction (drug)

A state of periodic or chronic intoxication produced by the repeated consumption of a drug (natural or synthetic). It is generally assumed to include: (1) an overpowering desire or need (compulsion) to continue taking the drug and to obtain it by any means; (2) a tendency to increase the dose; (3) a psychic

(psychological) and generally a physical dependence on the effects of the drug; (4) detrimental effect on the individual and on society. Because of its combining of compulsion, tolerance, physical dependence, psychological dependence, and detrimental effects, it is not a useful term and should be discarded.

"Double Blind"

A term used in research to indicate that neither the patient or subject nor the experimenter knows which of several drugs or placebo is given on any occasion. Considered a necessary condition if results are attributed to the effects of the drug as pharmacologic agent.

Dependence (drug)

A state of psychic or physical dependence, or both, on a drug, arising in a person following administration of that drug on a periodic or continuous basis. The characteristics of such a state will vary with the agents involved, and these characteristics should always be made clear by designating the particular type of drug dependence in each specific case.

Dependence (physical)

An adaptive state that manifests itself by intense physical disturbances when the administration of the drug is suspended or when its action is affected by the administration of a specific antagonist. Pre-

sence of a reliable withdrawal syndrome is considered evidence of physical dependence.

Dependence (psychic)

A feeling of satisfaction and a psychic drive that require periodic or continued administration of the drug to produce pleasure or to avoid discomfort; usually does not involve physiological withdrawal symptoms.

Depressant

Any agent that will depress (decrease) a body function or nerve activity. Depressants may be classified according to the organ or system upon which they act.

Habituation (drug)

A condition resulting from the repeated consumption of a drug. Its characteristics include: (1) a desire (but not a compulsion) to continue taking the drug for the sense of improved well-being which it engenders; (2) little or no tendency to increase the dose; (3) some degree of psychic dependence on the effect of the drug, but absence of physical dependence and hence of an abstinence syndrome; (4) detrimental effects, if any, primarily on the individual.

"Habit-forming drugs"

Legal: a drug which may produce any of the following: (1) a psychological or physical dependence on the drug (compulsive use); (2) euphoria (exaggerated sense of well-being); (3) personality changes; (4) transient

psychoses, deliria, twilight state, or hallucinoses;
(5) chronic brain syndrome; (6) increased tolerance
or a need or desire to increase the drug dosage.

(Regulations under Federal Food, Drug & Cosmetic Act,
January, 1966).

Hallucinogenic

Medical: producing hallucinations-false perceptions
having no relation to reality and not accounted for
by any external stimuli; may be visual, olfactory,
auditory, etc.

Hypnotic

A drug which induces sleep, usually refers to drugs
which induce normal sleep but may include all narco-
tics (medical).

Narcotic

Medical: A class of drugs which induce sleep and
stupor and relieve pain, includes opiates, anesthe-
tics, and others. Some pharmacologists include bar-
biturates although they do not relieve pain.

Legal: opium, its alkaloids and derivatives; the
coca leaf and its principal derivative, cocaine;
the plant *Cannabis sativa* L., otherwise known as
"marihuana"; and a specific class of synthetics
called "opiates" such as meperidine (Demerol) and
methadone.

Placebo

"medication" composed of pharmacologically inactive

ingredients, (saline solution, lactose, etc.) used as a control in drug research. Used in the same form as the drug for which it is being used as a control, (capsule, tablet, solution, etc.).

Stimulant

Any agent temporarily increasing functional activity. Stimulants may be classified according to the organ or system on which they act.

Tok

Also referred to as a "hit", tok refers to the amount of marihuana needed to completely burn after one maximum inhalation of the burning marihuana smoke.

Tolerance

An adaptive state characterized by diminished response to the same quantity of drug or by the fact that a larger dose is required to produce the same degree of pharmaco-dynamic effect.

CHAPTER II

REVIEW OF THE LITERATURE

HISTORICAL DEVELOPMENTS OF CANNABIS SATIVA

Ancient China was the site of the first recorded use of the hemp plant, known today as *cannabis sativa*. The emperor, Shen Nung, described its use as a medication in a Chinese drug compendium written around 2737 B.C.. At almost the same time, perhaps around 2,000 B.C., Hindu and Aryan writings, from India, indicate use of the hemp plant in religious ceremonies of that civilization, as a means of communicating with the gods. There is nothing to indicate that the intoxicant or euphorant effect of the plant was known. The medicinal effects were known however, and this use of the plant spread to the Middle East where the hemp plant was also used in making strong cloth.

In the Middle East, the plant is predominantly used in religious ceremonies. Herodotus, the Greek historian writing around 430 B.C., told of the after-funeral cleansing rites of the Scythians. These people, in the ceremony threw hemp seeds on hot coals, basked in the resulting "cannabis-scented vapor" (83) and then "howled for joy." There is no historical indication as to whether the Scythians were aware of the intoxicant effect of the plant but it is known that knowledge of this effect was beginning to develop and spreading quickly throughout the Orient. By the time use of the plant reached East and Southern Mediterranean and North Africa, the potency of the plant was

known.

Once the intoxicant effect was known, the countries began to develop different forms for the use of the plant. Originally, the people of India brewed the flowers of their local Indian hemp and consumed the drink called "Soma." However, by 800 B.C., they had developed "Charas" which is the most potent form of the euphorant. During the time of the crusades, the unfortunate activities of the fanatic Hassan caused one of the first negative reactions to the intoxicant. This Persian religious leader apparently fed a form of *cannabis sativa* to his army and somehow worked them up into "murderous fury " (83). Thus they would descend on an unsuspecting victim, of the leader's choosing, and would assassinate him. The words "hashish" and "assasin" have developed as a result of these escapades.

While all this was occurring in the Orient, Europe was still fairly naive of the euphorant effect of the plant. It grew wild in most parts of Europe certainly, and was also widely valued for its strong fibres for making fine rope and cloth but it was not until the eighteen hundreds, when Napoleon's men came in contact with Egyptian civilization that the potency became known. Just prior to this in 1753, Linnaeus, the Swedish botanist classified the plant and named it "*Cannabis sativa*." Once the euphorant reached France, its use in certain areas became prevalent. First the "Club des Haschichins" developed. A club comprised mostly of French intellectuals who considered con-

suming the euphorant the thing to do. Also, at this time, J.J. Moreau de Tours began what may have been the first scientific research with the plant, when he experimented with it in the treatment of mental illness. By the time of the colonization of North America, the English were well aware of the plants strong fibres and in fact later established hemp crops near Jamestown, in the New World.

However, it was not from her European ancestors that North America gained knowledge of the intoxicant, but rather from her southern neighbour. The Latin Americans may have learned of the plants potency from the Spanish but it seems more likely that, since a variety of the plant already grew in their area, that they developed the use themselves. Prior to the conquest in 1509, the Aztecs were using it in religious ceremonies and in fact South Americans were the first civilization to smoke the intoxicant.

The United States and Canada became aware of the preparation of *cannabis sativa*, known as marihuana, mainly through Mexican immigrants. At first it became the intoxicant of the poor and was used regularly in the slums of New Orleans especially by Negro jazz musicians (83). The plant itself was still considered as a medication and was last listed in United States Pharmacopoeia of 1937 (38). But the Marihuana Tax Act of 1938 in the United States caused use of the intoxicant to go underground. Even a fairly objective study on the use and

effects of the intoxicant, instigated by Mayor Le Guardia of New York, (64) was shunned by the governing public and severe legislation regarding the "drug" was made.

The trend in the use of marihuana today began in the nineteen-fifties when American artist intellectuals such as Aldous Huxley began experimenting with mind-expanding drugs. This experience was readily accepted by the North American youth and use of marihuana became widespread throughout North America. Naturally as this occurred, the need for objective studies was realized and thus research in marihuana has increased. However, before we review this recent research, let us discuss what factor causes the potency of the plant which in turn causes such controversy.

As indicated previously, cannabis sativa grows in almost any climate except extreme cold. The names of the varieties of the plant, for example, cannabis indica or cannabis americana, show where the variety grows and this has direct bearing on how potent the plant is.

The chemical makeup of the plant is extremely complex and the efforts to break down the structure in order to find what causes the potency of the plant are very young. Research has found that the plant contains a complex group of substances known as cannabinoids, (also known as cannabinoids). These are made of such derivatives as cannabinol proper, cannabidiol, cannabichromene, cannabigerol, cannabicyclol, tetrahydrocannabinols, the acids

of these derivatives and many others. In 1940, it was shown that the tetrahydrocannabinols, (known as THC), made up the primary active ingredient in the plant (2). Isbell et al (50) in September, 1968, were successful in isolating an isomer of THC, (-) D9 - Trans-tetrahydrocannabinol, referred to as D9-THC. This isomer, when administered separately to a human subject, produced the euphorant effect on the individual. This factor makes up the largest extent of the active ingredient, however, other components, to a lesser extent, also may contribute to the effect (38).

The plant is "dioecious" and it is found that the female plant produces a sticky yellow resin at the flower clusters and tops of most leaves. This resin is known to contain the greatest amount of the active ingredient. However, the ingredient can be found to a lesser extent in other parts of the plant and also in the male plant. The active ingredient also varies among all varieties and is affected by "...climate, the nature of soil, the amount of sunlight and water, the care and cultivation it receives, the stage at which it is harvested, the length of time and the way it is stored..." (83) to name only a few. Thus, we have plants of different potency and naturally there has developed different terms for the preparations of the plant within their regions.

India has three grades of preparations of cannabis sativa. "Charas", the most potent form is made up of the pure resin of the female plant. Today it is usually smoked with tobacco but can also be eaten. Although this prepara-

tion is illegal in India, the other two are not. "Ganja", made from the chopped-up flowering tops and the leaves of cultivated plants is also smoked but has less potency than charas. Dried leaves of mature wild plants brewed in a liquid constitutes "Bhang", the least potent of India's preparations.

The Middle East, like India, has an ideal climate for producing a high active ingredient in the plant. "Hashish", the Middle East's preparation would equal that of India's charas. It is made up of the powdered and sifted resin of the female plant. North Africa is familiar with hashish, except for Morocco where "Kif" made of the resin mixed with leaves and flowers is used and represents a lesser intoxicant. Then, of course, we have "Marihuana" which is made from the upper leaves and flowering tops of Mexican grown cannabis sativa or a weaker American variety. The Mexican grown plant is less potent than the plant of India and this preparation of marihuana would equal India's bhang in potency.

CURRENT RESEARCH ON CANNABIS SATIVA

Until the spectacular resurgence of use of marihuana by western society during the past decade, scientific interest had been largely dormant. But during the past few years, the interest has rekindled, in part because of its social importance, in part because of the possibility of doing more studies and because research funds have been made available.

The rate of increase in scientific inquiry has risen in an experimental manner after such a slow start while legal procedures were being ameliorated. Still, much of the newer work with marihuana involves the rediscovery of phenomena known for many years. Thus, by the late 1950's many of the phenomena of marihuana intoxication has been described. It was not until another ten years passed and a marked change in the patterns of use of the drug had occurred in the North American society that interest in clinical studies was again revived.

This section of the investigation will draw together some of the more recent information on marihuana. Doorenbos et al (32) and Dr. Harry G. Pars (80) along with Mechoulam (69) and Jasinski (51) discuss the various cultigens grown from seeds obtained from all over the world. These cultigens were analyzed for D^9 - Tetrahydrocannabinol and other cannabinoids and how they differ morphologically and chemically. Doorenbos et al (32) pointed out that the cannabinoid content varied in decreasing order from bracts to flowers to leaves, to small stems and is very low in seeds and roots and that D^9 THC was the most potent Tetrahydrocannabinol. This is also supported by Pars (80). Doorenbos also pointed out that there was no significant difference between male and female plants.

One major concern in investigated cannabinoids, is the method of administering the drug. Most authors, (98, 80, 68, 62, 44), point out that administering the drug

orally, subcutaneously, interperitoneally, or by smoking varies in the potency of the drug products and the time for it to take effect. The active compounds of cannabinoids are insoluble in water (80), therefore, take a longer time to be absorbed and are not always metabolized because by passing through the liver they get detoxified and thereby becoming inactive. (62, 68, 98) It is also suggested that D⁹-THC is more active when administered interperitoneally rather than subcutaneously (68) because of the formation of more active metabolites by the liver.

The inactive cannabinoid acids, (THC - acid A and THC - acid B), are converted to active D⁹-THC through decarboxylation (68) by smoking rather than by injection. Although Mechoulam (68) also points out that the burning process destroys some of the active D⁹-THC and therefore the actual dose being absorbed may be lower. But Manno (62) points out that since little is known about the absorption of THC from the lungs or gastrointestinal tract, it is not possible to determine accurately the amount of accumulated dose of THC that reaches the blood. Much more work is needed in this area.

Weil et al (98) also stated that the effects of the active cannabinoids do not last more than two or three hours and the effects start within seconds to minutes after smoking. Whereas oral doses delay the onset of intoxication from thirty minutes to two hours which supports Pars's theory (80) that the active D⁹-THC is water insoluble and therefore

will delay the onset of intoxication.

Before moving on to some of the physiological effects found by various researchers, a few words should be said regarding the break down and metabolism of the cannabinoids. A few preliminary remarks first. The inactive cannabinoid acids are made active when converted to D^9 -THC by smoking through the process of decarboxylation (68). Also, the active D^9 -THC if left in the open air is oxidized to cannabinol proper or inactive cannabinoid. The burning process will also destroy some of the D^9 -THC to an inactive cannabinoid isomer.

Because cannabinoids are insoluble in water, one must find a solution in which it is soluble for oral administration procedures. Machoulam (68) and Hollister (44) found that the cannabinoids are soluble in petroleum ether for laboratory analysis purposes.

Many studies deal with the metabolism of cannabinoids and specifically the Tetrahydrocannabinols (80, 95, 43, 61, 16, 22, 34, 45, 68, 76). It is generally felt and agreed that the main active cannabinoid is D^9 -THC and that it is metabolized completely in the body by hydroxylation to yield various metabolites. The two main metabolites formed are 7 - hydroxy and 11 - hydroxy analog (metabolite) (61, 95). Wall (95) and Lemberger (61) also discuss that it is the metabolite which is the active form of D^9 -THC. Their theory is supported by others (44, 68).

D^9 -THC was injected and tagged with C^{14} and its

disposition followed in the plasma, urine and feces (61). Lemberger (61) also found out that the 11 - hydroxy -THC metabolite appeared within ten minutes in the blood plasma. Negligible quantities appeared in the urine or feces. Also, Lemberger (61) professes that the drug Δ^9 -THC is completely metabolized in man.

One more point noted by Burstein (16) was that the 7 - hydroxy - THC metabolite from Δ^9 -THC was found in liver preparations. These metabolites were converted because of an enzyme system known as mono-oxygenase.

A few physiological findings have been recorded by a few researches. Le Guardia's (64) subjects reported increased appetite. But more recent advances by Weil et al (98), Ames (3) and Podolsky (81) reveal that there is no change in blood glucose levels. Podolsky (81) concluded that there was no hypoglycemia although there was a slight reduction in their Glucose Tolerance Test, (G.T.T.). He also found no impairment of insulin release in the body. On the other hand, Manno (62) spotted a change (increase) in blood glucose levels of his subjects but these levels were not significant. We can conclude that from the data available, more work is also needed in studying eating habits and blood glucose levels.

The only study to report anything on muscular strength was Hollister (44, 47). He measured muscle strength with the finger (middle) ergograph and demonstrated muscle weakness objectively.

Pulse rate and blood pressure are the two areas where most of the work has been done. Some investigators administered their drug orally (97, 3 47), some administered the drug by smoking (98, 45, 62, 64, 53, 31, 93, 35) while others administered the drug orally and by smoking (50, 54).

Isbell et al (50) and Hollister (47) reported that blood pressure was constant when the drug was administered orally. Isbell et al (50) also reported that blood pressure was constant after the drug was smoked. These findings were dose related. Le Guardia (64) and Domino (31) reported a rise in blood pressure but it was not a significant rise when the drug was smoked. Ames (3) also reported a rise in blood pressure but again was not significant when the drug was administered orally. Waskow (97) reported a drop in blood pressure after orally administering the drug. This again was not significant. Weil (98) felt that enough research was evident on blood pressure and therefore did not record blood pressure measures.

Heart rate is the most commonly reported physiological measure when dealing with the cannabinoid drugs (3, 31, 35, 45, 47, 50, 53, 54, 62, 64, 93, 97, 98). Forney (35), Volavka et al (93), Domino (31), and Isbell et al (50) reported that when their subjects smoked marihuana, they showed an increase in pulse rate which was significant and dose related. Weil et al (98) also showed a significant increase in pulse rate after smoking Δ^9 -THC; but it was

not dose related. Hollister (45), Manno et al (62), Le Guardia (64), and Jones (53, 54) showed significant increases in pulse rate after smoking marihuana; but only one dose was administered.

Pulse rates were also measured when the drug was administered orally. Isbell et al (50) found a significant dose related increase in pulse rate. After orally administering D⁹-THC, Hollister et al (47), Waskow et al (97), Ames (3) and Jones et al (54) demonstrated significant increases in pulse rate after the drug had been administered orally; but no comparisons with these investigators were made with various doses.

CHAPTER III

METHODS AND PROCEDURES

SUBJECTS AND MATERIAL

A sample of twenty volunteer human marihuana smokers selected at random was obtained to serve as subjects. The subjects were all male ranging in age from twenty-one to twenty-seven years. (See Table III, Page (46)). Eight of the subjects were university students with a few now out working in various occupations in the community. (Appendix A). They were, however, all considered average athletes according to their past participation and past level of performance. A thorough medical examination was completed on all subjects prior to the testing sessions. A history of the subjects' alcohol, cigarette and marihuana habits was recorded along with the medical report. The subjects agreed to a number of experimental conditions when they signed their release and completed medical form. Out of the twenty subjects, eighteen completed all testing sessions. The reason for the two subjects dropping out is explained in the discussion part of chapter four.

The marihuana and placebo plant material used in the testing sessions was supplied by the Division of Narcotics, Food and Drug Directorate, Department of National Health and Welfare, Ottawa. The 35 grams of cannabis sativa received was of the Mexican variety which contained 1.3% Δ^9 - Tetrahydrocannabinol, (hereafter known as Δ^9 -THC). Each subject was required to smoke 1.4 grams of the marihuana plant

material or 18.2 milligrams of D⁹-THC. The 35 grams of placebo material was also from the same mature cannabis sativa plant, except various chemical means were used to remove the D⁹-THC. Other chemical tests revealed negative results when the placebo material was tested for its D⁹-THC content. Subjects were also required to smoke 1.4 grams of placebo.

The subjects reported to the testing center for three testing sessions conducted on three different days in which the drugs were administered by the double-blind method. The laboratory was a very neutral setting in which very little conversation took place between the subjects and administrators. On the first day each subject came in to the laboratory at a set time, randomly selected, and completed the test protocol without smoking placebo or marihuana. This will be referred to as the Control Test. The variance between subjects is significant, pointing out the importance of using each subject as his own control in an assay (50). Each subject, on the next two testing days, completed the testing items on either marihuana or the placebo. There were three days between each subject's testing day and time. Also, each subject appeared at the same time of day for each testing sessions. All testing sessions were carefully supervised and the drugs administered by a qualified physician. Duration of the tests administered was one hour and fifteen minutes. The following table shows the time schedule and the order in which the para-

meters were administered.

TABLE I
SCHEDULE OF TESTING SESSIONS

TIME (HOURS)	PROCEDURE
0.00	Smoking Placebo or Marihuana and Resting Period
0.30	Resting Heart Rate Recorded
0.32	Blood Pressure Taken
0.35	Dominant and Nondominant Grip Strength Measures Recorded
0.40	Forced Vital Capacity and Flow Rates Taken
0.45	Sensitivity Threshold Measures Taken
0.50	Complex Coordination Tests Administered
1.00	PWC ₁₇₀ Administered
1.15	End of Testing Session

THE MARIHUANA AND PLACEBO GLASS PIPE



FIGURE 1

The placebo and marihuana plant material was smoked in a hand made glass pipe. (Figure 1). Each glass pipe bowl was fitted with a very fine metal mesh filter. This filter was replaced by a new one after each subject smoked his material. A "tok", (a small "hit"), was smoked at once in the bowl of the pipe. It took 20 - 25 "toks" to finish off the 1.4 grams of material. Each "tok" of smoke was inhaled and retained in the lungs for 7-10 seconds. As a result, this type of smoking and the kind of pipe used, there was very little escape of smoke into the atmosphere or wastage of marihuana from spilling or burning away.

DESCRIPTION OF PROCEDURES

A. Resting Heart Rate

The subject's resting heart rate was monitored by a Sanborn Electrocardiograph, (ECG). This heart rate was recorded on the testing form after the subject had completed smoking the marihuana and the placebo material and had relaxed about ten minutes. Resting heart rate was also recorded just before the PWC₁₇₀ test was administered once the subject was in position on the bicycle ergometer. For the control test, the resting heart rate was recorded ten minutes after the subject had arrived at the testing center and just before the PWC₁₇₀ test was administered.

B. Blood Pressure

This method is best described by Anthony (4).

Blood pressure was measured with the aid of an apparatus

known as a sphygmomanometer which makes it possible to measure the amount of air pressure equal to the blood pressure in an artery. The measurement is made in terms of how many millimeters high the air pressure raises a column of mercury in a glass tube.

The sphygmomanometer consisted of a rubber cuff attached by a rubber tube to a compressible bulb and by another tube to a column of mercury which is marked off in millimeters. The cuff is wrapped around the arm over the brachial artery, and air is pumped into the cuff by means of the bulb. In this way, air pressure is exerted against the outside of the artery. Air is added until the air pressure exceeds the blood pressure within the artery, or in other words until it compresses the artery. At this time no pulse can be heard through a stethoscope placed over the brachial artery at the bend of the elbow along the inner margin of the biceps muscle. By slowly releasing the air in the cuff, the air pressure is decreased until it approximately equals the blood pressure within the artery. At this point the vessel opens slightly and a small spurt of blood comes through, producing the first sound, one with a rather sharp, taplike quality. This is followed by increasing louder sounds which suddenly change, becoming more muffled, then disappearing altogether. The nurse must train herself to hear these different sounds and to read the column of mercury at the same time since the first taplike sound represents the

systolic blood pressure, that is, the force with which the blood is pushing against the artery walls when the ventricles are contracting. The lowest point at which the sounds can be heard, just before they disappear, is approximately equal to the diastolic pressure or the force of the blood when the ventricles are relaxed. Systolic pressure gives valuable information about the force of the left ventricular contraction and diastolic pressure gives valuable information about the resistance of the blood vessels. Clinically, diastolic pressure is considered more important than systolic pressure because it indicates the pressure or strain to which blood vessel walls are constantly subjected and also reflects the condition of the peripheral vessels since diastolic pressure rises or falls with the peripheral resistance.

The subject's blood pressure was measured and recorded on the testing forms after the resting heart rate was measured and recorded.

C. Grip Strength

A manometer, or hand dynamometer, of the stoelting type, was used to measure grip strength, both dominant and nondominant hands being tested, (Figure 11), (25, 99). These measures were taken after the blood pressure was recorded in each session.

1. The tester took the right hand corner of the manometer between the thumb and forefinger of his right hand

and placed it in the palm of the subject's dominant hand while holding the hand to be tested with his left hand in such a manner that the convex edge of the manometer was between the first and second joints of the fingers and the rounded edge was against the base of the hand. The thumb should touch, or overlap, the first finger. The dial of the manometer was placed face down in the hand.

2. In taking the test, the subject's elbow was slightly bent and his hand described a sweeping arc downward as he squeezed the manometer. The hands were not to be allowed to touch the body, or any object, while the test was being administered. If they do, the score was not read at all, and a retest was given after a short rest period of thirty seconds.

3. The dominant hand was tested first and then the nondominant. Scores were read to the nearest kilogram.

4. A cake of magnesium carbonate was available for dusting the hands if they became moist or slippery.

5. The indicator was returned to zero after each test.

THE STOELTING DYNAMOMETER

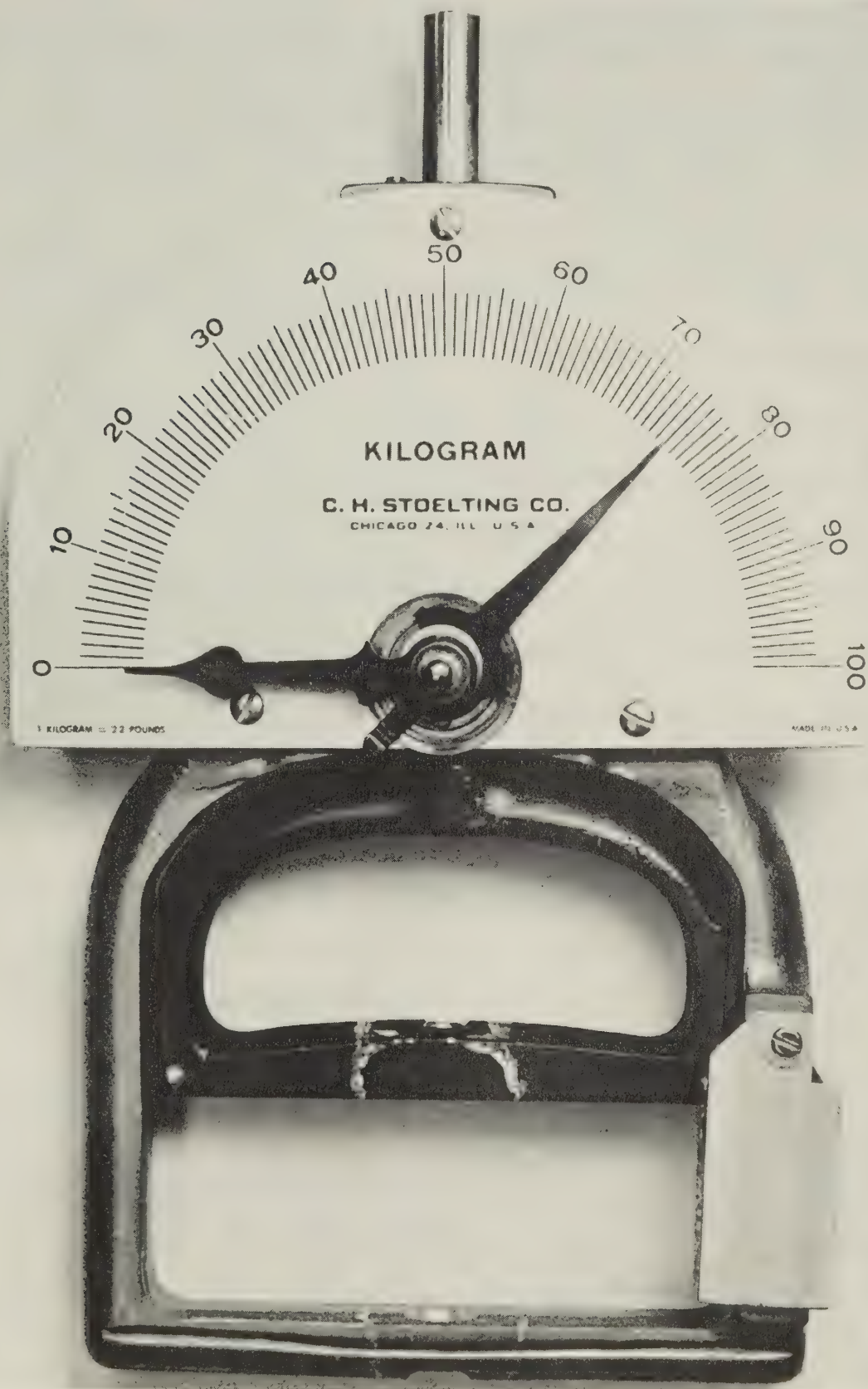


FIGURE 11

1. Forced Vital Capacity

A line "AB" was drawn and measured on the graph paper. This distance in millimeters multiplied by a factor, (32.04), and divided by 1,000 resulted in the forced vital capacity in liters.

2. Flow Rate (0-25%)

Draw a line "LN" through the "O" and "X", (25%), points and extend it. From any point on line "N" on this line, measure a 20 millimeter distance, (one second), "MN". Draw a perpendicular line "LM" meeting the "LN" line at "L". Multiple "LM" by the factor 32.04 and divide by 1,000 and this gives you the flow rate in liters per second.

3. Flow Rate (25-75%)

Repeat the above methods only using the extended line "XY" for 25-75% flow rate.

E. Sensitivity Threshold

The Semmes-Weinstein Pressure Asthesiometer is a modern adaptation of the long recognized Von Frey technique for the establishment of sensitivity threshold. Von Frey originated the technique of using horse hairs of differing lengths, bent against the skin, to produce differing pressures. The force exerted against the skin is a function of the length and diameter of the hair and remains constant without regard to the bend of the hair, producing a simple means of exerting a constant known force.

The Semmes-Weinstein set consisted of a precisely calibrated series of nylon filaments of equal length,

(thirty-eight millimeters), and varying diameters set into individual lucite rods. The log force exerted by these filaments yields a linear function, providing an interval scale for the computation of thresholds. The setting of the filaments into individual rods permitted the test to be administered in a very rapid and simple manner for maximum subject comfort and examiner convenience.

The nylon filament was far superior to natural horse hair for these purposes. It had high resistance to change brought about by fatigue or exposure to chemicals or light, thus provided a consistent and stable unit of force. It can be sterilized in alcohol without detrimental effects.

The complete testing set had a total of twenty individual mounted filaments in a fitted case. The range of forces available was from 0.0045 to 447.0 grams, broad enough to enable threshold determination from among the most sensitive body parts in a range of subjects from normal to those with any severe impairment of somatic sensation.

The subjects placed both hands in a covered box. They were to respond positively to the examiner when they felt any sensation on their fingertips. Both the dominant and nondominant index fingers were tested. The subjects did not know which finger or hand was tested. Therefore, only correct responses to the pressure asthesiometer were recorded.

F. Complex Coordination Test

The subject was placed in a darkened room and required to make motor adjustments of an airplane-type stick and rudder, (pilot simulator), in response to successively presented visual patterns, (79) (Figure III). The visual patterns consisted of three parallel rows of lights. Three rows were red and three corresponding parallel rows were green. Each new pattern appeared in red while the green lights were moveable upon movement of the rudder and stick. The rudder controlled the upper horizontal row of green lights. If the rudder was moved to the right, the corresponding green light moved to the right, and vice versa to the left. The stick controlled the movement of the green lights in the perpendicular and lower horizontal rows. When the stick moved forward and backward, the corresponding green lights moved down and up respectively on the perpendicular row. When the stick moved to the right or to the left, the green light in the lower horizontal row moved to the right or to the left, the green light in the lower horizontal row moved to the right or left respectively. A correct response, (movement of the stick and rudder controls to the proper positions), was not accomplished until both of the hands and feet completed and maintained the appropriate adjustment and the three green and three red lights were matched up. A new pattern appeared automatically at random as each correct response was completed. The score was the number of correct responses completed in a given

test period. Each test period was one hundred seconds with four trials given. This test followed the sensitivity threshold test in each session.

THE PILOT SIMULATOR FOR COMPLEX COORDINATION



FIGURE III

G. Physical Work Capacity

1. The Theory Underlying the Test.

Hellinger and associates, (41) state that

"...during prolonged heavy physical work the individual's performance capacity depends largely on his ability to take up, transport and deliver oxygen to the working muscle. Consequently the maximal oxygen uptake, (or aerobic capacity), is probably the best method of assessing physical fitness, providing the definition of physical fitness is the ability to do prolonged heavy physical work."

But maximal tests are, time consuming, require knowledge of elaborate laboratory procedures on the part of the testers, require extreme effort on the part of the test subjects and require expensive and elaborate equipment.

With these points disfavoring the maximal tests, Hellinger and associates, (41:153), proved there was a high correlation between maximal test results and results obtained with submaximal tests such as the Sjostrand Bicycle Ergometer Test in determining the work capacity at a given heart frequency. With this proof in mind, it is believed justifiable to accept the results obtained there as being close to those that could be obtained with maximal test.

The subjects underwent the modified submaximal Sjostrand bicycle ergometer test as the last item of the testing sessions, as outlined in the booklet by Metivier and Orban (72).

2. The General Description of Modified Sjostrand Test.

Changes in circulation, respiration and metabolism

can be studied during and after work. Consequently, the bicycle ergometer has become an important aid in the evaluation of the physical work capacity, (PWC_{170}), and of cardiovascular condition.

One indirect method in measuring the physical work capacity of an individual is the Sjostrand (85) and modified Wahland (94) and subsequently used extensively in Sweden by Sjostrand. The modified Sjostrand, used in this study, measures physical work capacity concurrent with a steady-state heart rate of one hundred seventy beats per minute, (PWC_{170}). Bicycling has proven to be a very suitable work form, since, among other things, at a given load, (submaximal), it demands about the same energy output, whether the subject is young or old, trained or out of condition, elite bicyclist or unfamiliar with the sport.

In research directed at the regulation of respiration and circulation, the investigation must be extended to work tests, including both submaximal and maximal work. Observation of the subject during muscular work can yield important information in an evaluation of circulatory function. A decrease in the heart's pumping capacity may not be detectable at rest, with a demand for a cardiac output of 4 - 5 liters, but certainly will be so if the load, as a result of work, is a cardiac output of 10 - 15 liters per minute or more. Within the clinic, as well as in preventive medicine, it may be worthwhile to apply a workload corresponding to the subject's normal daily energy requirements.

If this test load can be measured exactly, one can follow how the reaction to the load changes as a result of training, placebo or marihuana.

This test is relatively cheap to run, easy to transport the equipment and it only requires submaximal energy expenditure. The simplicity of the testing procedures facilitate any training of testing teams and it also demonstrates a high relationship with maximal oxygen intake tests.

The bicycles were calibrated before and after the three testing sessions. The calibration factors, established by hanging standard masses on the revolving drum, (Figure IV), were the number of grams required to raise the pendulum to each successive scale marking. A factor was therefore derived for each of the fourteen scale divisions.

CALIBRATION OF BICYCLE ERGOMETER

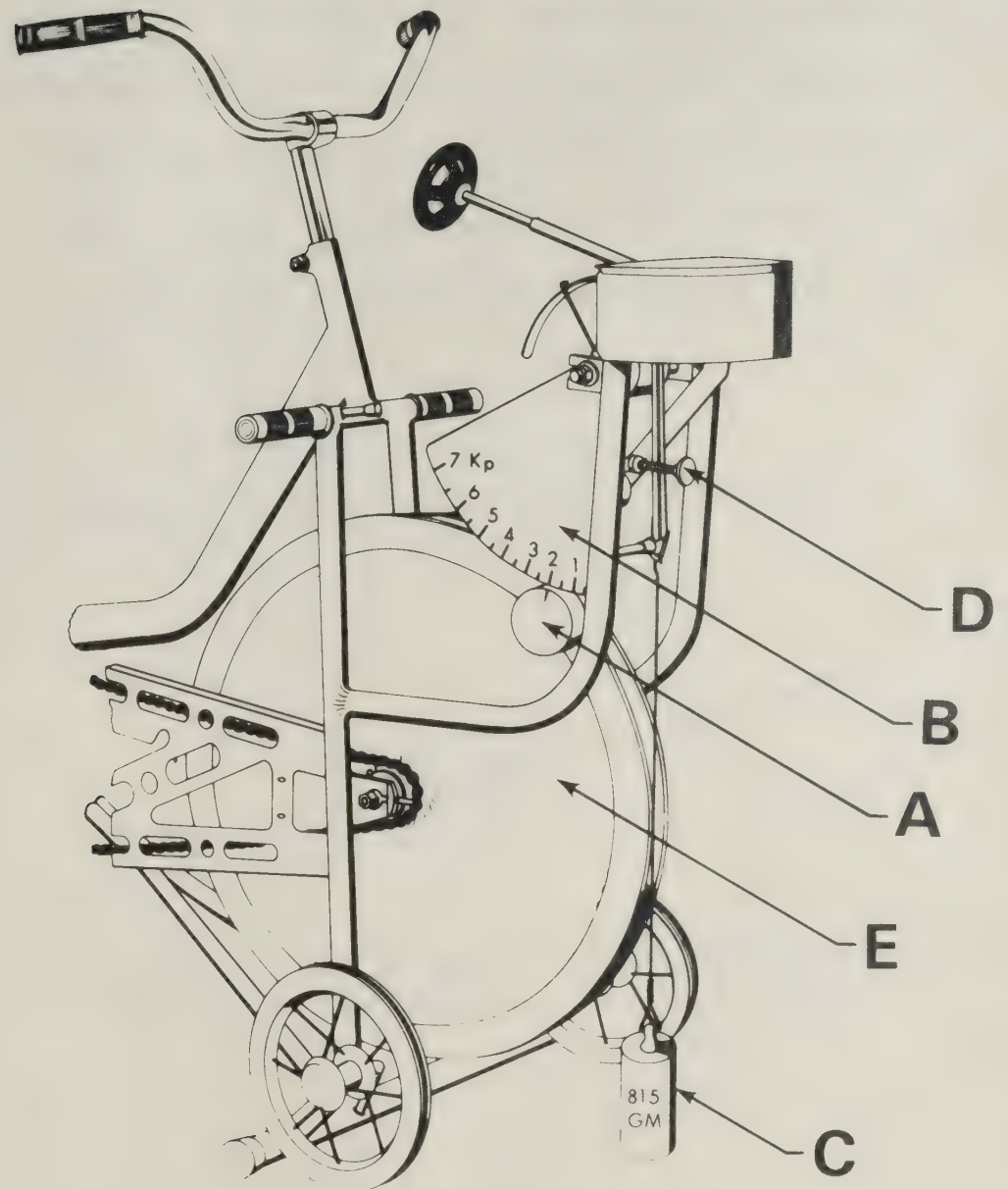


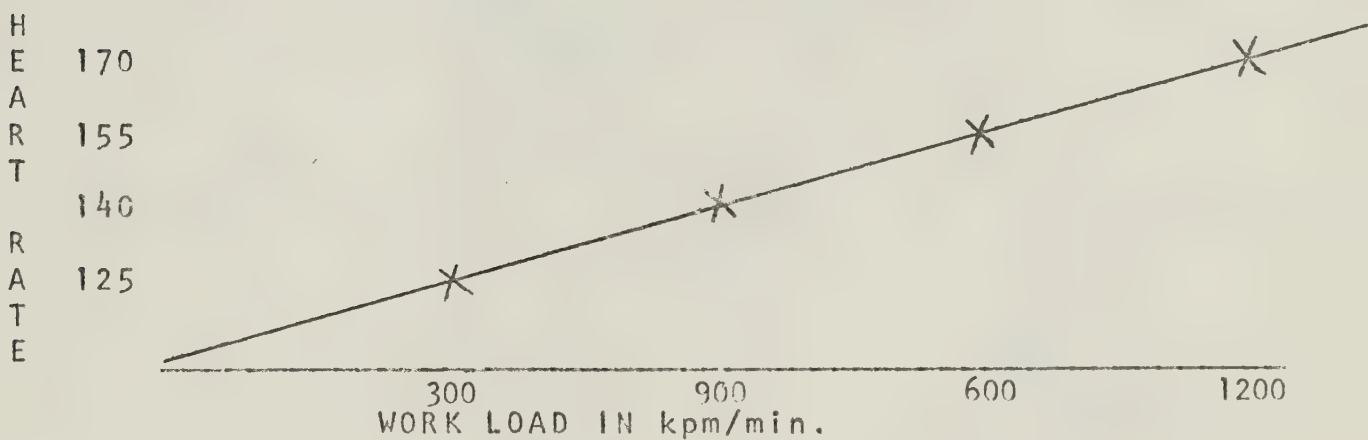
FIGURE IV

FIGURE IV SHOWS THE CALIBRATION TECHNIQUE FOR ONE SCALE SETTING ONLY. THE FLY WHEEL (E) IS LOOSENED AT THE AXLE AND PUSHED BACK SO THAT THE LIGHT STRING SUPPORTING THE WEIGHT HANGS FREE. TILTING THE ERGOMETER UP AT THE REAR AND READJUSTING THE SCALE (B) TO 0 SCALE READING WHEN THERE IS NO WEIGHT ON THE STRING, USING THE WING NUT (D), AIDS IN PROVIDING CLEARANCE OF THE STRING FROM THE WHEEL. THE WEIGHT (C) REQUIRED TO RAISE THE PENDULUM (A) IS ALSO SHOWN. A CALIBRATION FACTOR IS ESTABLISHED FOR EACH SCALE DIVISION, 1, 1.5, 2, 2.5 etc.

The test as modified involved riding a bicycle ergometer for a total of twelve minutes, four minutes at each of three progressively heavier workloads. The heart rate of each subject was monitored by a sanborn electrocardiograph, (ECG), at the end of each four minute period of exercise. There is a direct relationship between the work done by an individual and the heart rate of an individual, (Table II).

TABLE II

RELATIONSHIP BETWEEN THE WORK DONE AND THE HEART RATE



SINUS BALANCE, SCALE AND TENSION REGULATING
MECHANISM OF BICYCLE ERGOMETER

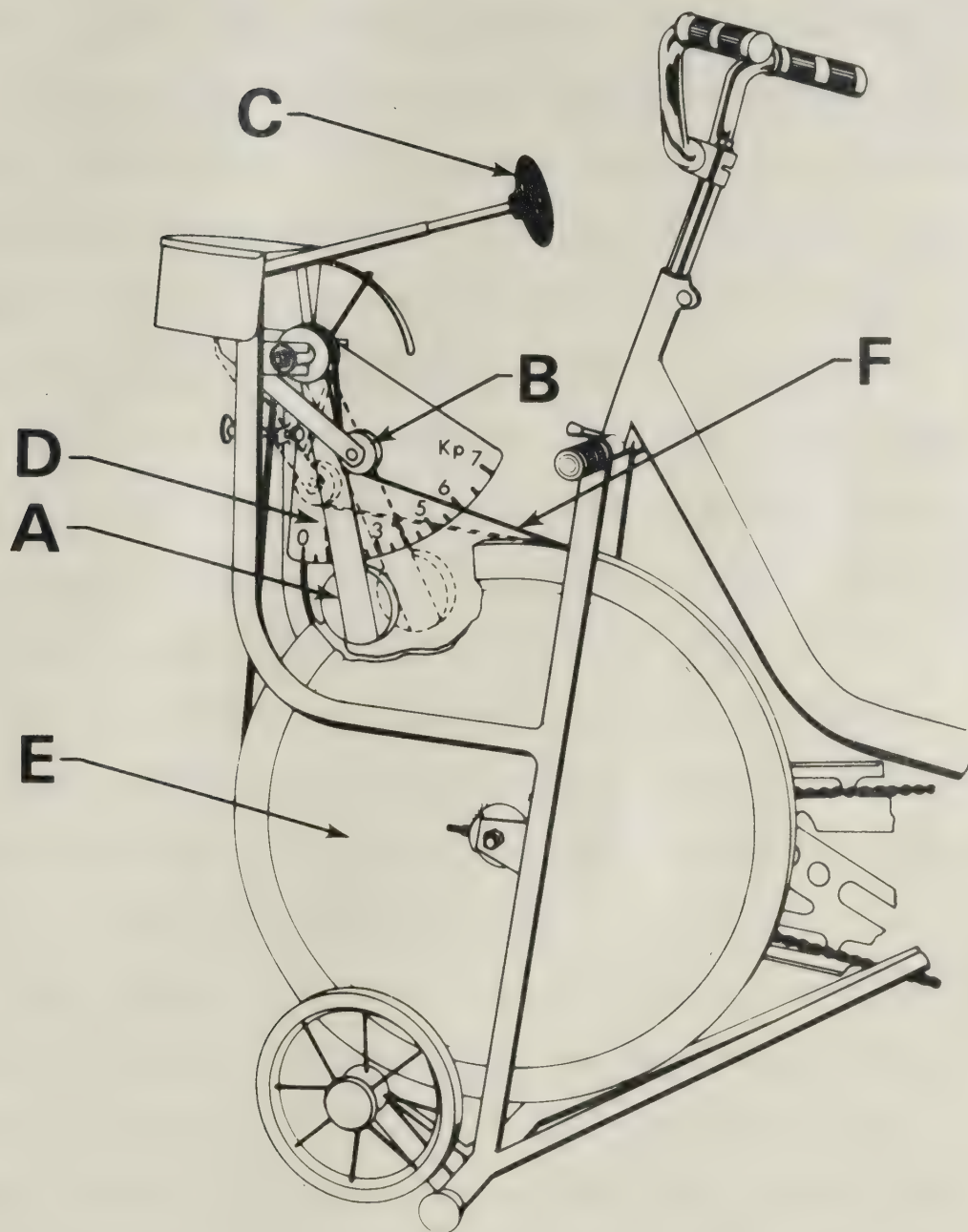


FIGURE V

FIGURE V SHOWS THE SINUS BALANCE, SCALE (D), AND TENSION REGULATING MECHANISM ON THE BICYCLE ERGOMETER (B, C). DOTTED LINES SHOW THAT WHEN THE TENSION ON THE BELT IS INCREASED THE PENDULUM RISES TO A HIGHER POINT ON THE SCALE. GREATER FORCE MUST BE APPLIED WITH THE LEGS TO THE PEDALS WITH THE PENDULUM AT THIS NEW SCALE POSITION.

A -- PENDULUM

B -- LEVER CONTROLLING TENSION ON BELT

C -- HANDWHEEL CONTROLLING
LEVER

D -- SCALE

E -- FLY WHEEL

F -- BELT

The sinus balance scale, (Figure V), was set at zero by loosening the belt until it exerted no tension. Care was taken to be sure the pedals were not touched during this part of the procedure. The seat was adjusted so that the subject felt comfortable. The patient leads were connected from the subject to the ECG as he sat on the bicycle ergometer. The subject, throughout his twelve minute ride, synchronized his pedal frequency by means of an electric metronome set at one hundred, (fifty complete revolutions per minute). Pedal revolutions were also recorded on an electric counter. At the end of each four minute interval, the heart rate, pedal revolutions and work load were recorded on the test form. Conversion charts were used to convert the ECG reading to heart rate per minute. The work load was increased at the end of each four minute interval.

STATISTICAL TREATMENT

For the purpose of this research project, a one-way analysis of variance, (correlated), was used for most of the variables involved. However, a two-factor analysis of variance with repeated measures on factor "B", (Time), was used for the Complex Coordination Test. The one-way analysis of variance was the method used for dividing the variation observed in experimental data into different parts, and the writer could assign a source, cause, or factor to each part of the variance. It was used to test the significance of the difference between the means of a number of different samples. Tested were the effects of "k" treat-

ments, (control, placebo and marihuana). A different treatment was applied to each of the samples, with each sample being comprised of "N", (eighteen) members. The members were assigned to the treatments at random and treated in each treatment by the double-blind method as mentioned before. The null hypothesis was formulated for each parameter tested that the samples are drawn from populations having the same mean, ($H_0: U_1 = U_2$). Some variations due to sampling fluctuation is expected between means; but we assume that the variances in the population from which the samples are drawn are equal, (homogeneity of variance). We assume also that the variables in the population are normal and the effects of various factors on the total variation are additive.

A table was constructed, (Appendix A), to collect the raw data for each variable or parameter. After this was finalized, an analysis of variance table was drawn up for each parameter followed closely by a concluding statement about the null hypothesis depending on the results, (F), obtained.

Following the application of the "F" test, a meaningful interpretation of the data required a comparison of pairs of means, if the set of "k" means differed significantly by the analysis of variance. We want to know how the means differ. Is every mean significantly different from every other? Are there significant differences between some of the means and not between others?

A variety of methods exist for determining multiple

comparisons in the ANOVA. Methods have been developed by Scheffe (1953) and Duncan (1955-1957), Newman-Keuls, Tukey and others. These different methods adopt different criteria for the acceptance or rejection of the null hypothesis. In making multiple comparisons among the treatment means, Newman-Keuls method between ordered means was used when a significant "F" was found.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

A. Mean and Range Values for Age, Height and Weight

Mean and range values for age, height and weight for the eighteen subjects who participated in the investigation are given in Table III.

TABLE III

MEAN AND RANGE VALUES FOR AGE, HEIGHT AND WEIGHT

PARAMETER	MEAN ($\bar{X}$)	RANGE
Age (years)	23.1	21 - 27
Height (inches)	70.3	66.0 - 75.0
Weight (pounds)	152.4	128.0 - 186.0

B. Resting Heart Rate

One variable measured in the investigation was the change in resting heart rate mean in the control session, after smoking a placebo in the placebo session and after smoking marihuana in the marihuana testing session. Changes in the resting heart rate means for the three treatment groups are shown in Table IV.

TABLE IV

RESTING HEART RATE VALUES

TREATMENT	MEAN ($\bar{X}$)	VARIANCE (s^2)	STANDARD ERROR OF THE MEAN ($\sqrt{\frac{s^2}{N}}$)
Control	73.7	106.6	2.43
Placebo	78.1	194.9	3.29
Marihuana	105.8	225.5	3.54

Figure VI graphically depicts the mean values and standard error of the mean values for resting heart rate between the three treatment groups.

MEAN RESTING HEART RATE SCORES FOR TREATMENT GROUPS

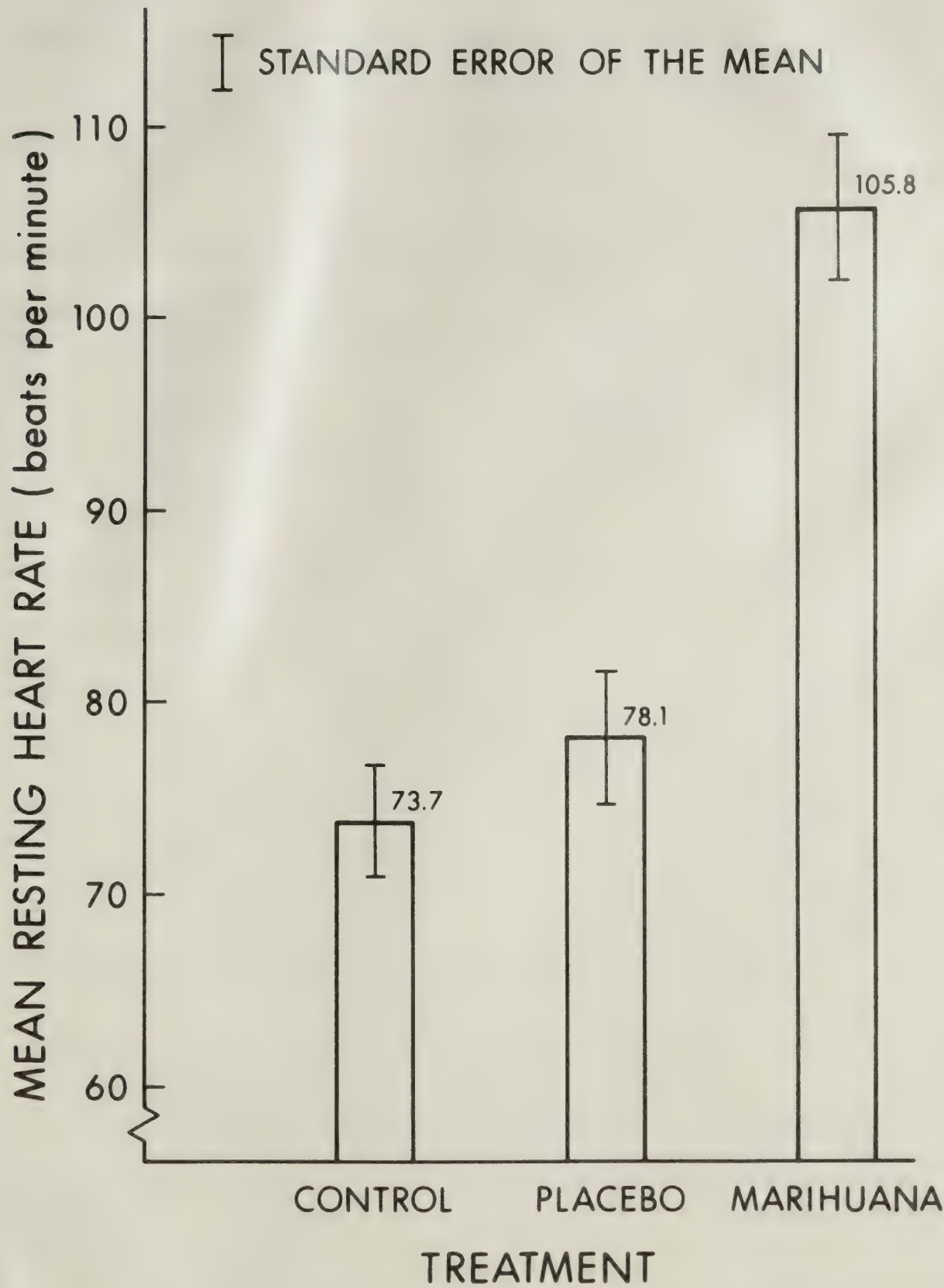


FIGURE VI

The existence of difference in the resting heart rate means for the three treatment groups were tested for significance by a one-way analysis of variance. Table V indicates the summary of the analysis. A significant difference occurred at the 0.05 level.

TABLE V

ANALYSIS OF VARIANCE FOR RESTING HEART RATE SCORES

SOURCE OF VARIANCE	SUMS OF SQUARE	DF	MEAN SQUARE	F
Groups	10873.75	2	5436.88	30.95*
Error	8958.5625	51	175.66	
Total	19832.3125	53		

* Significant at the 0.05 level.

Because a significant F was found, Newman-Keuls comparison between ordered means was employed as illustrated by Table VI. As a result of this, it was shown that there was a significant difference between the control group and the marihuana group, a significant difference between the placebo group and the marihuana group, but no significant difference between the control group and the placebo group all at the 0.05 level of significance.

TABLE VI

SUMMARY OF NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR RESTING HEART RATE

MEANS	3 (MARIHUANA) 105.8	2 (PLACEBO) 78.1	1 (CONTROL) 73.7
1. (Control 73.7	32.056 *	4.389	0.0
2. (Placebo) 78.1	27.667 *	0.0	
3. (Marihuana) 105.8	0.0		

* Significant at the 0.05 level.

C. Blood Pressure

The second set of variables to be investigated was the change in systolic and diastolic blood pressure in the three treatment groups. Changes in systolic and diastolic blood pressure means for the three treatment groups are shown in Table VII and VIII respectively.

TABLE VII

SYSTOLIC BLOOD PRESSURE VALUES

TREATMENT	MEAN ($\bar{x}$)	VARIANCE (s^2)	STANDARD ERROR OF THE MEAN ($\frac{s}{\sqrt{n}}$)
Control	121.1	154.7	2.93
Placebo	122.2	129.4	2.68
Marihuana	133.4	175.9	3.13

TABLE VIII

DIASTOLIC BLOOD PRESSURE VALUES

TREATMENT	MEAN ($\bar{x}$)	VARIANCE (s^2)	STANDARD ERROR OF THE MEAN ($\frac{s}{\sqrt{n}}$)
Control	77.4	84.8	2.17
Placebo	80.5	72.7	2.01
Marihuana	92.3	158.2	2.97

Figure VII depicts the mean values and standard error of the mean values for systolic and diastolic blood pressure for the three treatment groups.

MEAN SYSTOLIC AND DIASTOLIC BLOOD PRESSURE SCORES
FOR TREATMENT GROUPS

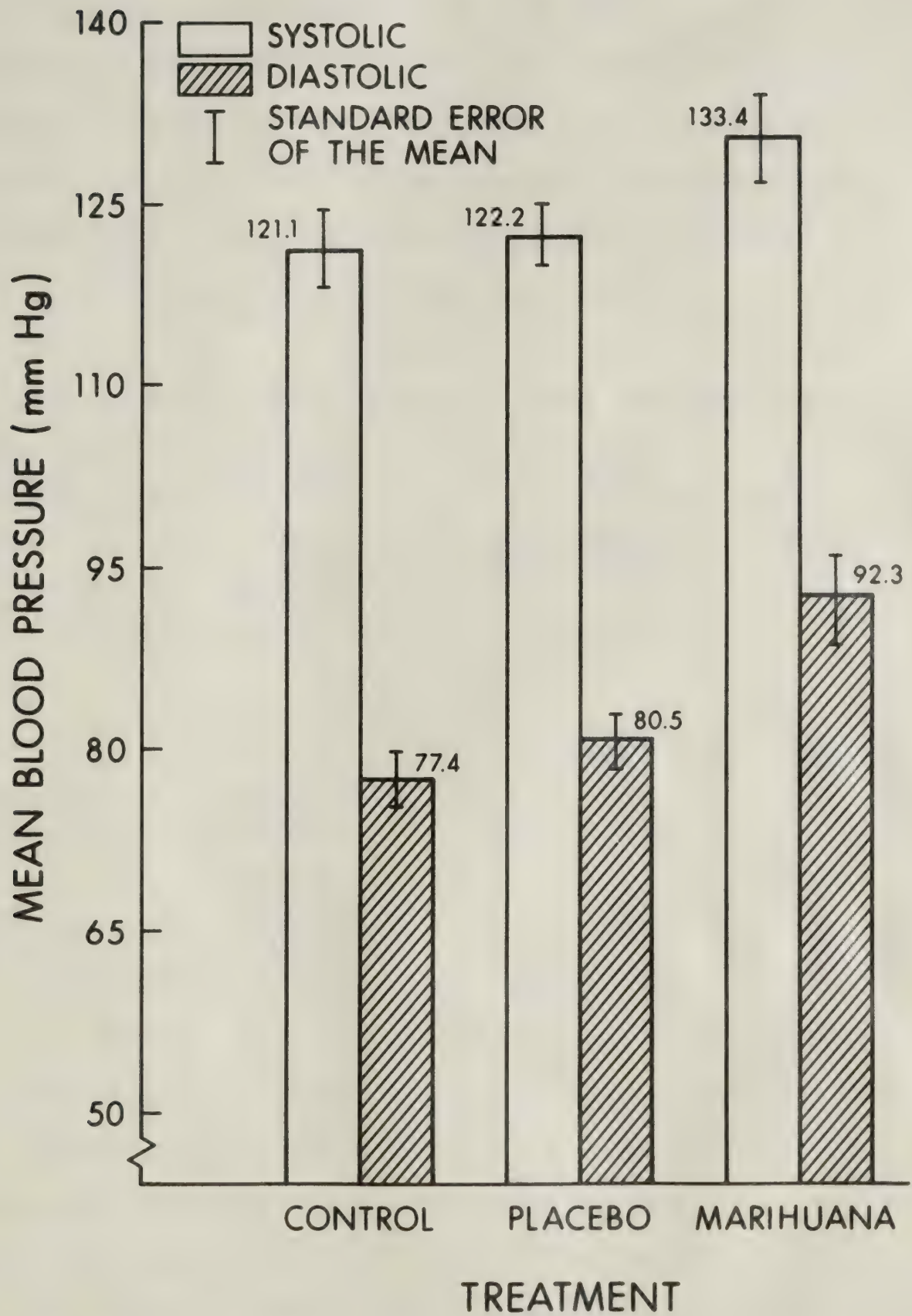


FIGURE VII

The existence of differences in the systolic and diastolic means, separately, for the three treatment groups were tested for significance by a one-way analysis of variance. Tables IX and X summarize each analysis of variance for the systolic and diastolic blood pressure. A significant F was found to occur at the 0.05 level for both systolic and diastolic blood pressure.

TABLE IX

ANALYSIS OF VARIANCE FOR SYSTOLIC BLOOD PRESSURE SCORED

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	1684.75	2	842.38	5.49 *
Error	7818.625	51	153.31	
Total	9503.375	53		

* Significant at the 0.05 level.

TABLE X

ANALYSIS OF VARIANCE FOR DIASTOLIC BLOOD PRESSURE SCORES

SOURCE OF VARIANCE	SUM OF SQUARES	DF	MEAN SQUARE	F
Group	2238.25	2	1119.12	10.63 *
Error	5368.8125	51	105.27	
Total	7607.0625	53		

* Significant at the 0.05 level.

A significant F was found for both systolic and diastolic blood pressure, therefore, Newman-Keuls comparison between ordered means was applied to both. This is illustrated as summaries in Table XI and XII. Here it is shown that there is a significant difference in blood pressure, (both systolic and diastolic), between the control and marihuana group and between the placebo and

and marihuana group at the 0.05 level of significance. No significant difference at the 0.05 level was found between the control and placebo group for systolic and diastolic blood pressure.

TABLE XI

SUMMARY OF NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR SYSTOLIC BLOOD PRESSURE

MEANS	3 (MARIHUANA)	2 (PLACEBO)	1 (CONTROL)
	133.4	122.2	121.1
1. (Control)			
121.1	12.389 *	1.167	0.0
2. (Placebo)			
122.2	11.222 *	0.0	
3. (Marihuana)			
133.4	0.0		

* Significant at the 0.05 level.

TABLE XII

SUMMARY OF NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR DIASTOLIC BLOOD PRESSURE

MEANS	3 (MARIHUANA)	2 (PLACEBO)	1 (CONTROL)
	92.3	80.5	77.4
1. (Control)			
77.4	14.944 *	3.111	0.0
2. (Placebo)			
80.5	11.833 *	0.0	
3. (Marihuana)			
92.3	0.0		

* Significant at the 0.05 level.

D. Physical Work Capacity

This variable was investigated to see if there was any change in the PWC₁₇₀ means for the treatment group. The PWC₁₇₀ values for the three treatment groups are illustrated in Table XIII.

TABLE XIII
PWC₁₇₀ VALUES

TREATMENT	MEAN(X)	VARIANCE (S ²)	STANDARD ERROR OF THE MEAN ($\frac{S}{\sqrt{N}}$)
Control	1177.2	76792.4	65.36
Placebo	1099.2	54400.9	55.01
Marihuana	829.9	45410.6	50.26

Figure VIII graphically depicts the PWC₁₇₀ mean values and standard error of the means value for the three treatment groups.

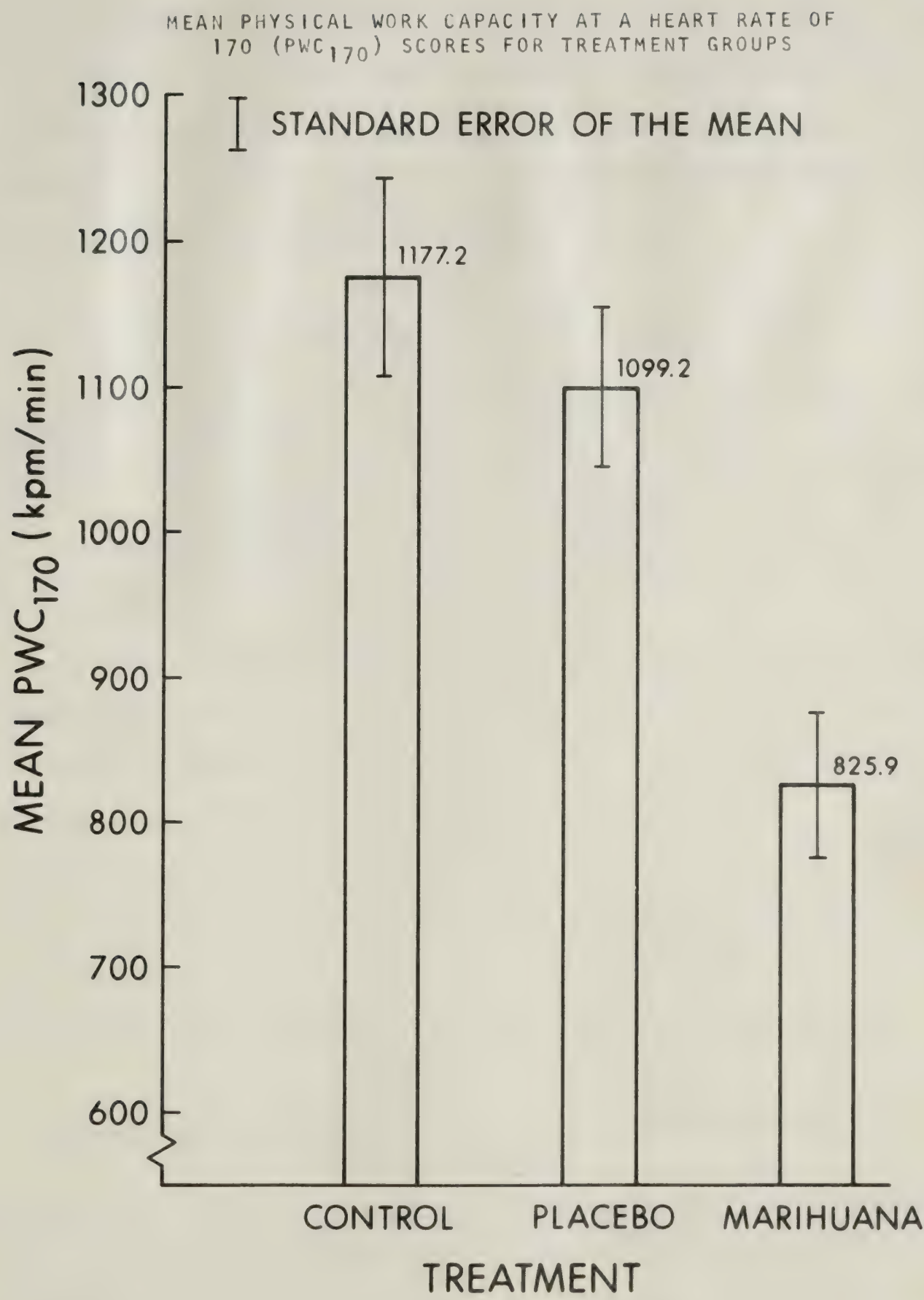


FIGURE VIII

Because differences in PWC_{170} means were evident from Figure XIII for the three treatment groups, a one-way analysis of variance was applied. The summary of this analysis is found in Table XIV. A significant difference in PWC_{170} was found at the 0.05 level.

TABLE XIV
ANALYSIS OF VARIANCE FOR PWC_{170} SCORES

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	1225024.0	2	612512.0	10.40 *
Error	3 002272 .0	51	58868.08	
Total	4227296.0	53		

* Significant at the 0.05 level.

Now that a significant F was found to exist for PWC_{170} , Newman-Keuls comparison between ordered means was employed. A summary of Newman-Keuls comparison for PWC_{170} mean scores for the three treatment groups is found in Table XV. As a result, there was a significant difference between the control and marihuana group and between the placebo and marihuana group at the 0.05 level. But no significance was evident at the 0.05 level between the control and placebo group.

TABLE XV
SUMMARY OF NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS OF PWC_{170}

MEANS	3 (MARIHUANA) 825.9	2 (PLACEBO) 1099.2	1 (CONTROL) 1177.2
1. (Control) 1177.2	351.300 *	78.033	0.0
2. (Placebo) 1099.2	273.267 *	0.0	
3. (Marihuana) 825.9	0.0		

* Significant at the 0.05 level.

PWC/Kg. of Body Weight was also computed for each treatment group. These values for the three treatment groups are illustrated in Table XVI.

TABLE XVI
PWC₁₇₀ BODY WEIGHT SCORES

TREATMENT	MEAN ($\bar{X}$)	VARIANCE (s^2)	STANDARD ERROR OF THE MEAN ($\frac{s}{\sqrt{N}}$)
Control	16.96	10.83	0.78
Placebo	15.77	6.05	0.58
Marihuana	11.83	5.28	0.54

Because differences in PWC₁₇₀/Kg. Body Weight means were evident from Figure XVI for each treatment group, a one-way analysis of variance was applied. The summary of this analysis is found in Table XVII. A significant difference in PWC₁₇₀/Kg. Body Weight was found at the 0.05 level.

TABLE XVII
ANALYSIS OF VARIANCE FOR PWC₁₇₀/Kg. BODY WEIGHT SCORES

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	259.36328	2	129.68	17.56*
Error	376.67578	51	7.39	
Total		53		

*Significant at the 0.05 level

Now that a significant F was found to exist for $PWC_{170}/Kg.$ Body Weight, Newman-Keuls comparison between ordered means was employed. A summary of Newman-Keuls comparison for $PWC_{170}/Kg.$ Body Weight mean scores for the three treatment groups is found in Table XVII. As a result, there was a significant difference between the control and marihuana group and between the placebo and marihuana group. No Significance was evident between the control and placebo groups.

TABLE XVIII

SUMMARY OF NEWMAN-KEULS COMPARISON BETWEEN ORDERED
MEANS OF $PWC_{170}/Kg.$ BODY WEIGHT

MEANS	3 (MARIHUANA) 11.83	2 (PLACEBO) 15.77	1 (CONTROL)
1. (Control) 16.96	5.129*	1.193	0.0
2. (Placebo) 15.77	3.936*	0.0	
3. (Marihuana) 11.83	0.0		

*Significant at the 0.05 level

Along the same lines of thought, predicted MVO_2 was calculated for each subject in each treatment group. These values are given in Table XIX

TABLE XIX
 MVO_2 SCORES

TREATMENT	MEAN ($\bar{X}$)	VARIANCE (S^2)	STANDARD ERROR OF THE MEAN ($\frac{S}{\sqrt{N}}$)
Control	3.18	0.14	0.09
Placebo	3.04	0.19	0.10
Marihuana	2.32	0.19	0.10

The differences shown in Table XIV suggested the application of a one-way analysis of variance. The summary of this analysis is found in Table XX. A significant difference in Predicted MVO_2 was found at the 0.05 level.

TABLE XX
ANALYSIS OF VARIANCE FOR MVO_2 SCORES

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	7.8002930	2	3.90	22.11*
Error	8.9953613	51	0.18	
Total	16.7956543	53		

*Significant at the 0.05 level

Newman-Keuls comparison between ordered means was employed because a significant F was found. A summary of Newman-Keuls comparison for predicted MVO_2 mean scores for the three treatment groups is given in Table XXI. As a result, a significant difference between the control and marihuana group and between the placebo and marihuana group was found. No significant difference was found between the control and placebo group.

TABLE XXI
SUMMARY OF NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS MVO_2

MEANS	3 (MARIHUANA) 2.317	2 (PLACEBO) 3.044	1 (CONTROL) 3.183
1. (Control) 3.183	0.867*	0.139	0.0
2. (Placebo) 3.044	0.728*	0.0	
3. (Marihuana) 2.317	0.0		

*Significant at the 0.05 level

E. Grip Strength

Another pair of variables investigated were the dominant and nondominant grip strength means. The investigator wanted to find out if there was any change in the means of grip strength for the three treatment groups for either the dominant or nondominant hands. The dominant grip strength scores are summarized in Table XXII while the nondominant grip strength scores are shown in Table XXIII

TABLE XXII

GRIP STRENGTH SCORES (DOMINANT HAND)

TREATMENT	MEAN ($\bar{x}$)	VARIANCE (s^2)	STANDARD ERROR OF THE MEAN ($\frac{s}{\sqrt{n}}$)
Control	53.3	30.4701	1.30
Placebo	54.1	21.6861	1.10
Marihuana	52.2	22.8176	1.13

TABLE XXIII

GRIP STRENGTH SCORES (NONDOMINANT HAND)

TREATMENT	MEAN ($\bar{x}$)	VARIANCE (s^2)	STANDARD ERROR OF THE MEAN ($\frac{s}{\sqrt{n}}$)
Control	52.2	24.2089	1.16
Placebo	51.0	20.0046	1.05
Marihuana	48.8	12.3541	0.83

Figure IX shows the required mean values and standard error of the mean values for grip strength, (dominant and nondominant hands), in the three treatment groups.

MEAN DOMINANT AND NONDOMINANT HAND GRIP STRENGTH
SCORES FOR TREATMENT GROUPS

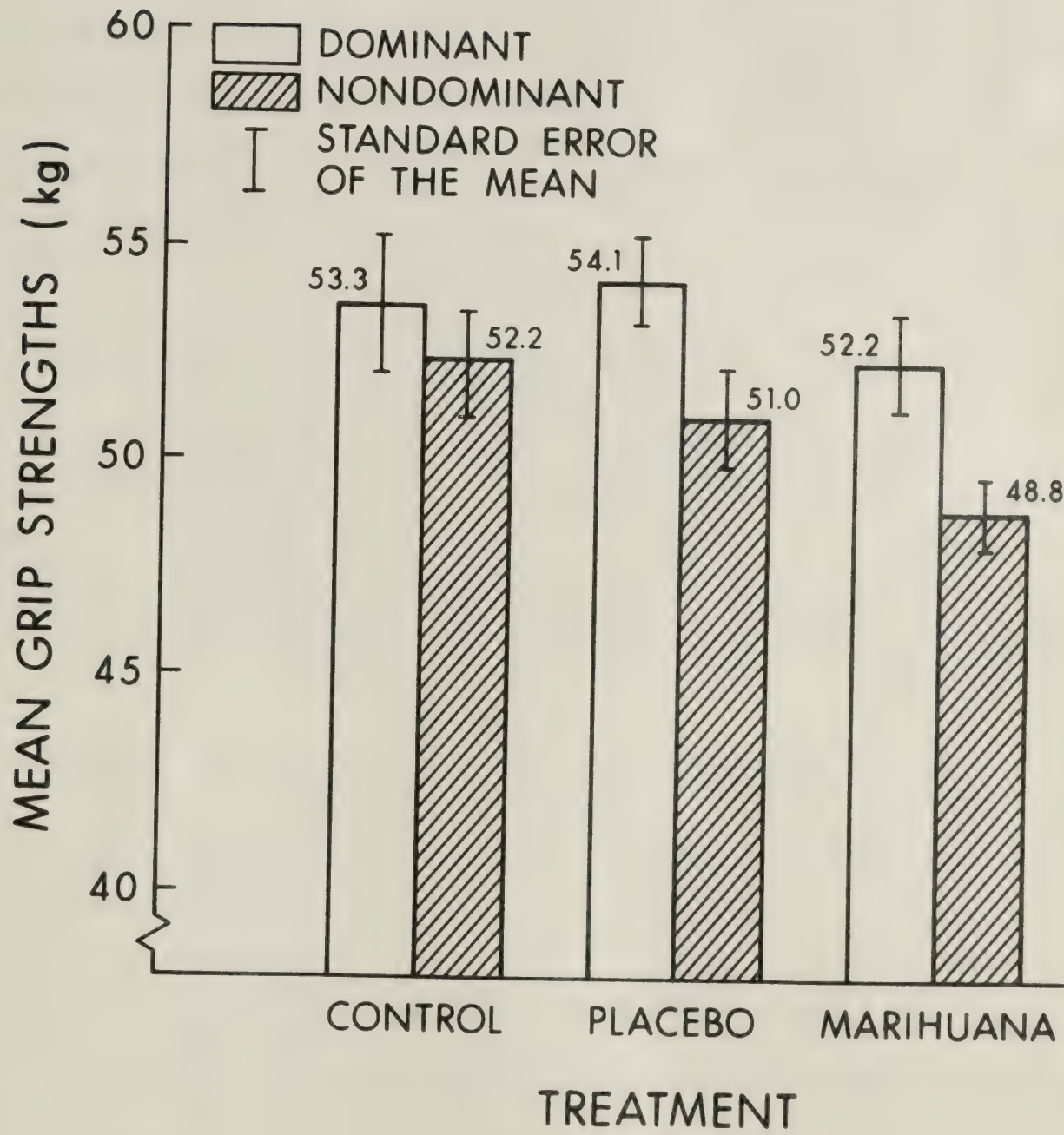


FIGURE IX

It is evident from Figure IX that differences are present in the means for grip strength, (dominant and non-dominant hand), for the three treatment groups. Therefore, a one-way analysis of variance was applied to the data. This summary of analysis is found in Tables XXIV and XXV. It is evident from Tables XXIV and XXV that no significance occurred at the 0.05 level between the control and placebo group, between the control and marihuana group or between the placebo and marihuana group.

TABLE XXIV
ANALYSIS OF VARIANCE FOR GRIP STRENGTH SCORES
(DOMINANT HAND)

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	34.000	2	17.00	0.68
Error	12.745	51	24.99	
Total	46.745	53		

3.23 was required for a significant F at the 0.05 level.

TABLE XXV
ANALYSIS OF VARIANCE FOR GRIP STRENGTH SCORES
(NONDOMINANT HAND)

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	105.4375	2	52.72	2.80
Error	961.6250	51	18.86	
Total	1067.0625	53		

3.23 was required for a significant F at the 0.05 level.

F. Forced Vital Capacity and Flow Rate

Other variables of the present investigation were to determine, if any, changes in the subject's forced vital capacity of the lungs and the flow rate of expired gases

from the lungs from 0-25% and 25-75%. These scores were measured for the three treatment groups; control session, after smoking placebo session and after smoking marihuana session. Tables XXVI, XXVII and XXVIII summarize the data collected for the forced vital capacity flow rate from 0-25% and flow rate from 25-75%.

TABLE XXVI

FORCED VITAL CAPACITY SCORES

TREATMENT	MEAN ($\bar{X}$)	VARIANCE (S^2)	STANDARD ERROR OF THE MEAN ($\frac{S}{\sqrt{N}}$)
Control	5.1	0.4003	0.17
Placebo	5.1	0.5898	0.21
Marihuana	5.0	0.4723	0.18

TABLE XXVII

FLOW RATE (0-25%)

TREATMENT	MEAN ($\bar{X}$)	VARIANCE (S^2)	STANDARD ERROR OF THE MEAN ($\frac{S}{\sqrt{N}}$)
Control	5.2	2.1742	0.39
Placebo	5.7	2.4101	0.42
Marihuana	5.0	1.6197	0.38

TABLE XXVIII

FLOW RATE (25-75%)

TREATMENT	MEAN ($\bar{X}$)	VARIANCE (S^2)	STANDARD ERROR OF THE MEAN ($\frac{S}{\sqrt{N}}$)
Control	4.1	1.1105	0.28
Placebo	4.2	0.8474	0.25
Marihuana	4.3	1.1087	0.28

On the basis of the data collected, Figure X was constructed to illustrate the mean values and standard error of the mean values for forced vital capacity, flow rate

from 0-25% and flow rate from 25-75% for the three treatment groups.

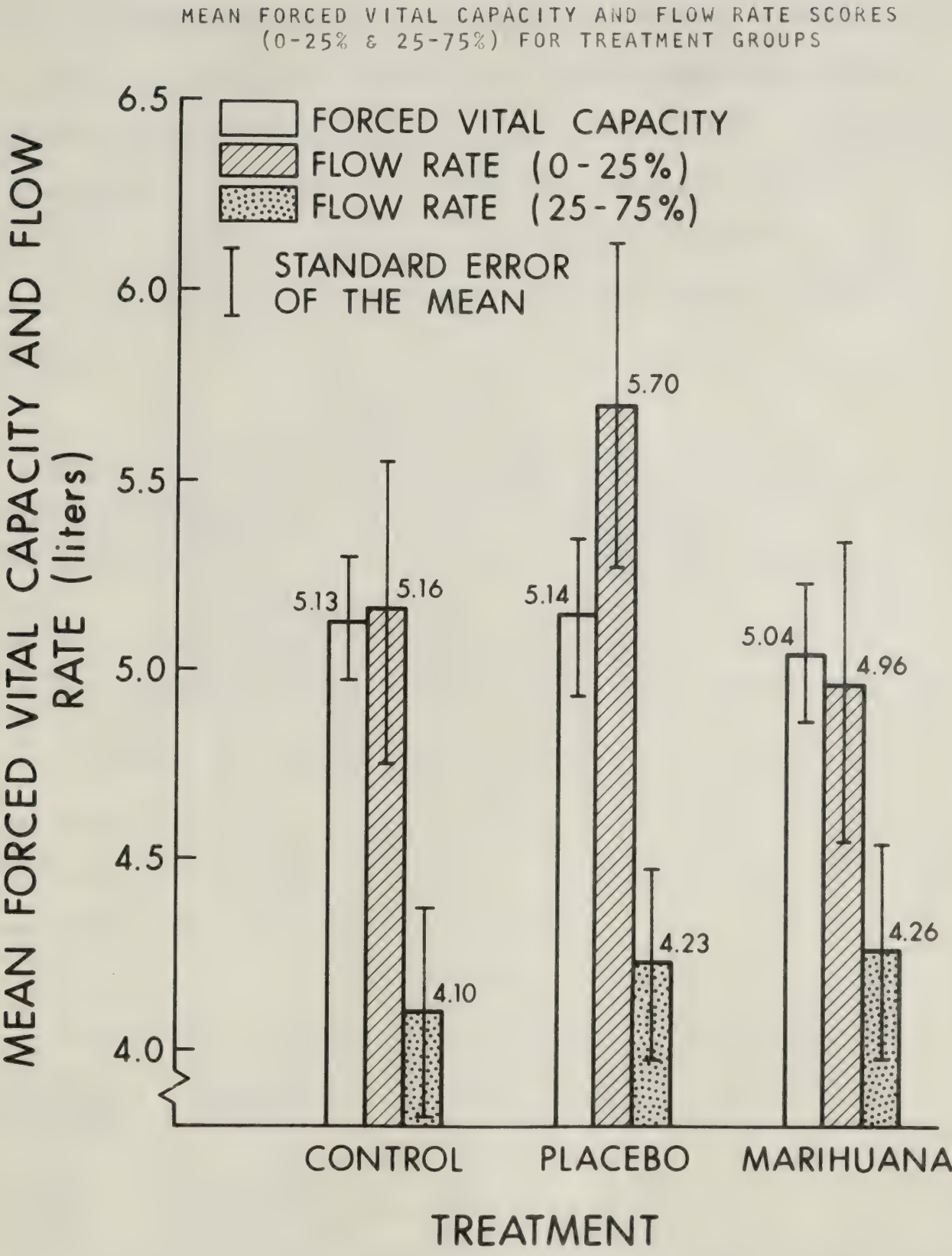


FIGURE X

On the basis of the existence of differences found in means from Figure X for the three different variables in the three treatment groups, it is necessary to apply a one-way analysis for each variable. Table XXIX summarizes the analysis of variance for the forced vital capacity. It was found that no significant difference occurred at the 0.05 level for the forced vital capacity between treatment means.

TABLE XXIX
ANALYSIS OF VARIANCE FOR FORCED VITAL CAPACITY

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Group	7.8369141	2	0.04	0.08
Error	19.0117190	39	0.49	
Total	26.8486331	41		

3.32 was required for a significant F at the 0.05 level.

Table XXX summarizes the analysis of variance for the flow rate from 0-25%. It was shown that at the 0.05 level no significant difference occurred between the treatment means for flow rate from 0-25%.

TABLE XXX
ANALYSIS OF VARIANCE FOR FLOW RATE FROM 0-25%

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	4.0783691	2	2.04	1.99
Error	80.6521000	39	2.07	
Total	84.7304691	41		

3.32 was required for a significant F at the 0.05 level.

Table XXX summarizes the analysis of variance for the flow rate from 25-75%. It was shown that at the 0.05

level that no significant difference occurred between the treatment means for the flow rate from 25-75%.

TABLE XXXI

ANALYSIS OF VARIANCE FOR FLOW RATE FROM 25-75%

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	0.2109375	2	0.11	0.10
Error	39.8657230	39	1.02	
Total	40.0766605	41		

G. Sensitivity Threshold

Another variable investigated was the sensitivity threshold in the subject's dominant and nondominant index fingers. The investigation was to determine changes, if any, in the mean sensitivity thresholds between the three treatment groups. Tables XXXII and XXXIII summarize the sensitivity threshold scores calculated for the dominant and nondominant hand respectively.

TABLE XXXII

SENSITIVITY THRESHOLD SCORES (DOMINANT HAND)

TREATMENT	MEAN ($\bar{X}$)	VARIANCE (S^2)	STANDARD ERROR OF THE MEAN ($\frac{S}{\sqrt{N}}$)
Control	2.92	0.1531	0.09
Placebo	2.96	0.1432	0.09
Marihuana	3.01	0.2024	0.11

TABLE XXXIII

SENSITIVITY THRESHOLD SCORES (NONDOMINANT HAND)

TREATMENT	MEAN ($\bar{X}$)	VARIANCE (S^2)	STANDARD ERROR OF THE MEAN ($\frac{S}{\sqrt{N}}$)
Control	2.94	0.1755	0.10
Placebo	3.03	0.1477	0.09
Marihuana	3.16	0.2024	0.11

On the basis of the data from Tables XXXII and XXXIII Figure XI was constructed to illustrate the mean values and standard error of the mean values for sensitivity thresholds, (dominant and nondominant hands), for the three treatment groups.

MEAN DOMINANT AND NONDOMINANT HAND SENSITIVITY
THRESHOLD SCORES FOR TREATMENT GROUPS

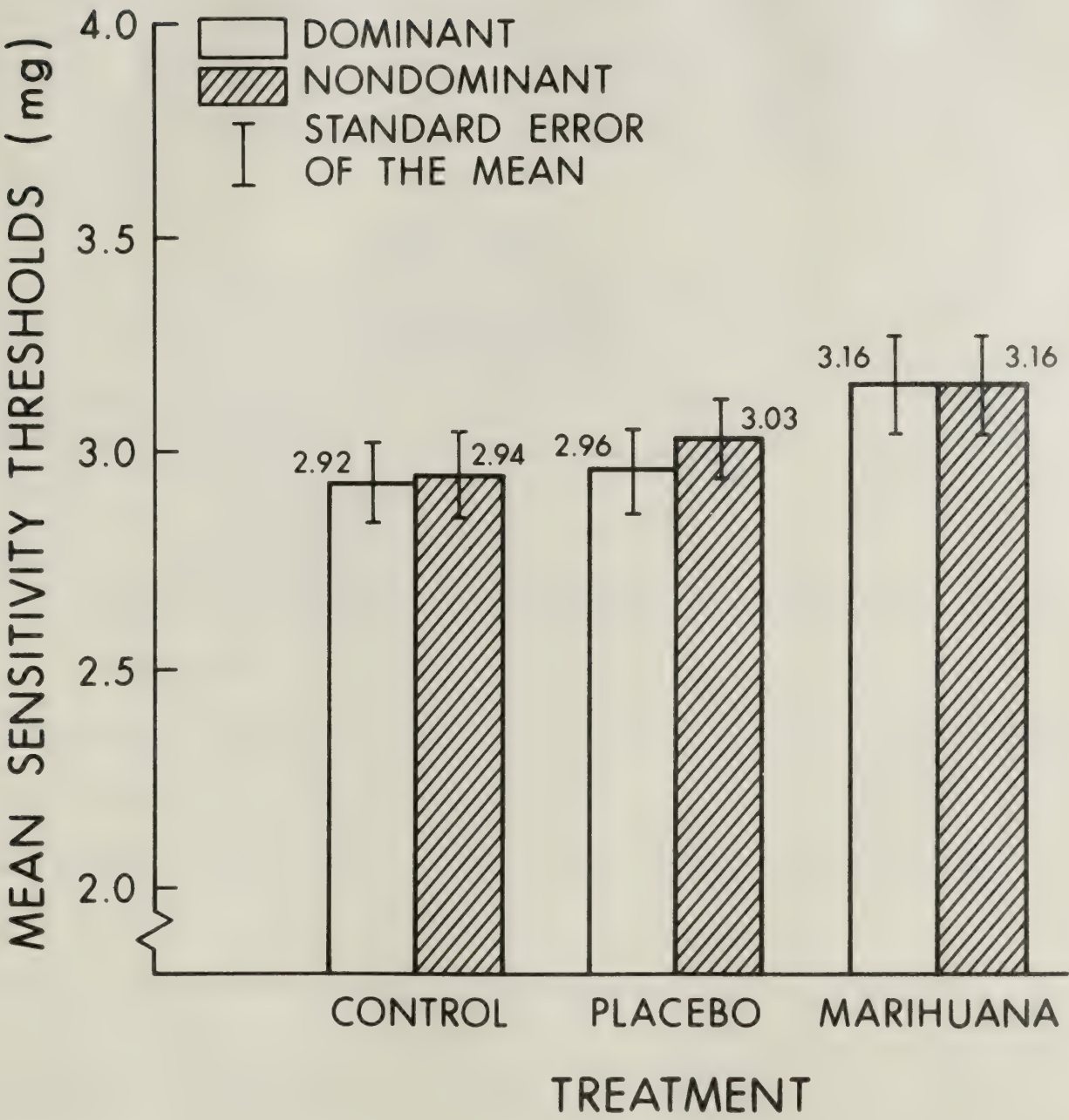


FIGURE XI

Because of the existence of differences in the mean of the three treatment groups for both dominant and non-dominant hands for sensitivity thresholds, an analysis of variance was applied to both. Table XXXIV illustrates the analysis of variance for dominant sensitivity threshold scores. No significant difference occurred at the 0.05 level for the dominant hand between the three treatment group means.

TABLE XXXIV

ANALYSIS OF VARIANCE FOR SENSITIVITY THRESHOLD SCORES
(DOMINANT HAND)

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	0.60058594	2	0.30	1.81
Error	8.47778320	51	0.17	
Total	9.07836914	53		

3.23 was required for a significant F at the 0.05 level.

Table XXXV illustrates the analysis of variance for nondominant sensitivity threshold hand scores. Again, no significant difference occurred at the 0.05 level for the nondominant hand between the three treatment group means.

TABLE XXXV

ANALYSIS OF VARIANCE FOR SENSITIVITY THRESHOLD SCORES
(NONDOMINANT HAND)

SOURCE OF VARIANCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
Groups	0.444333594	2	0.22	1.27
Error	8.934570300	51	0.18	
Total	9.378903894	53		

3.23 was required for a significant F at the 0.05 level.

H. Complex Coordination

The last variable investigated was complex coordination, measured with the use of a pilot simulator as described in Chapter III. The investigation was to determine any changes in complex coordination between the three treatment groups over a period of four time trials. Table XXX summarizes the means calculated for each treatment group at each time trial for complex coordination.

TABLE XXXVI
COMPLEX COORDINATION SCORES

TREATMENT	TRIAL (MEANS $\bar{X}$)			
	1	2	3	4
Control	12.83	14.61	14.78	16.00
Placebo	16.28	19.11	18.50	19.72
Marihuana	13.22	17.17	17.72	16.89

On the basis of the data in Table XXXVI, it was evident that two figures be constructed. Figure XII illustrates the complex coordination scores of the four time trials for each treatment group and Figure XIII illustrates the complex coordination scores of the treatment group for each time trial.

MEAN COMPLEX COORDINATION SCORES OF THE FOUR TIME TRIALS FOR EACH TREATMENT GROUP

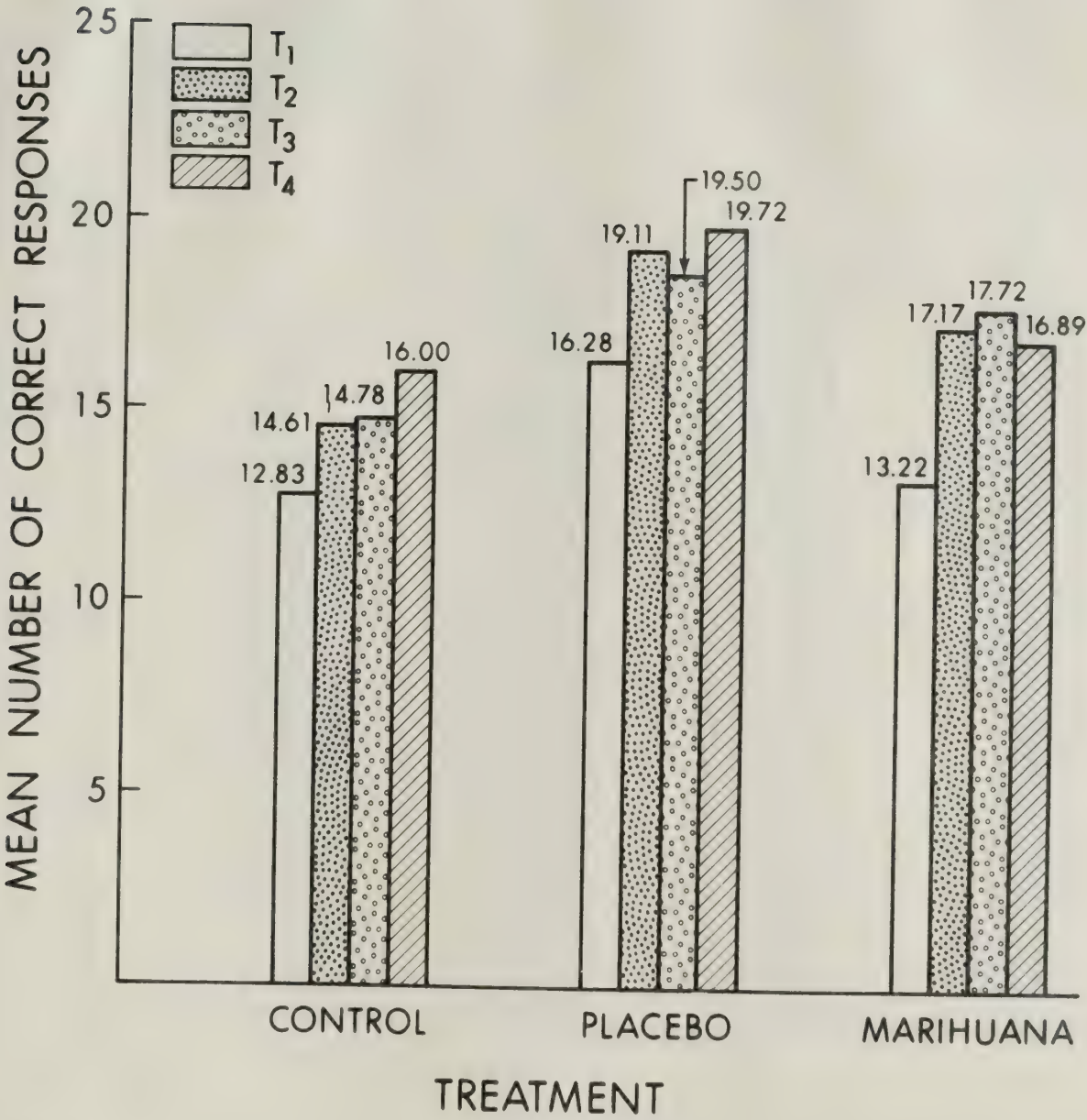


FIGURE 11

MEAN COMPLEX COORDINATION SCORES OF THE TREATMENT GROUPS FOR EACH TIME TRIAL

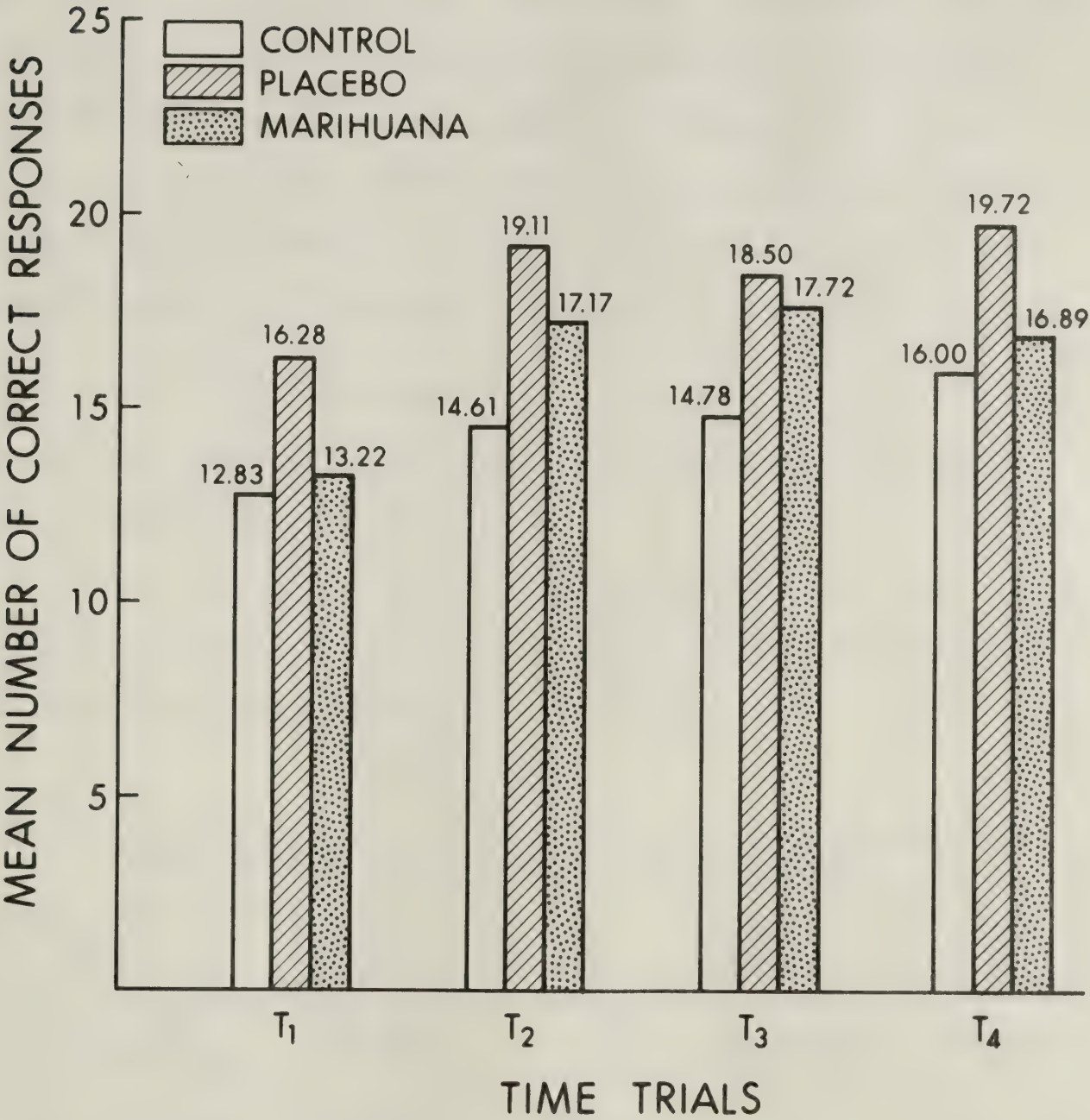


FIGURE XIII

There existed differences in the means of the three treatment groups and the four time trials, therefore, a two-way factor analysis of variance with repeated measures on factor "B" was employed. Table XXXVII summarizes the two-way factor analysis of variance for complex coordination. As a result of this table, three statements can be made:

1. "A" main effects showed a significant F, which means that the control, placebo and marihuana groups are significantly different at the 0.05 level regardless of time.

2. "B" main effects showed a significant F, which means that time was significantly different at the 0.05 level regardless of treatment.

3. The effect of treatment over time was not significant at the 0.05 level. In other words, no treatment effects the groups differently over time.

TABLE XXXVII

TWO-FACTOR ANALYSIS OF VARIANCE WITH REPEATED MEASURES ON FACTOR "B" FOR COMPLEX COORDINATION SCORES

SOURCE OF VARIANCE	SUM OF SQUARES	DF	MEAN SQUARE	F
Between Subjects	2720.711	53		
"A" Main Effect	535.333	2	267.667	6.247 *
Subjects Within Groups	2185.352	51	42.850	
Within Subjects	929.250	162		
"B" Main Effect	389.224	3	129.741	40.589 *
"AxB" Interaction	51.007	6	8.501	2.660
"B" x Subject Within Groups	489.059	153	3.196	

* Significant at the 0.05 level.

DISCUSSION

Several results from this study show quite a marked individual variation in response to cannabis. The results also raise important questions about the action of marihuana and suggest directions for future research. Despite the individual variation one could discern, in all cases, a common basic pattern of response. All subjects experienced a curious disturbance of consciousness, a disorder of time perception, and difficulty in immediate recall. Accompanying these mental changes, the constant physical changes were pulse rate, blood pressure and physical work capacity.

The disturbance of consciousness is difficult to define. For the first one-half hour or so, there was in most cases a waxing or waning of contact with reality, or, more correctly, a constriction of the field of awareness. Despite this, the capacity for self-observation appeared to be heightened and most subjects responded relevantly if stimulated. Several of them denied any disturbance of consciousness, maintaining that they were fully aware of their surroundings and the nature and purpose of the investigation. But to the observer, there was undoubtedly a definite though often subtle and elusive change in the degree or direction of awareness in all cases. Also, the subjects were in a state of sustained hilarity accompanied by excited talking after smoking marihuana. This did not take place after the placebo smoking. The idea of the investigation would suddenly seem enormously amusing, to the subject, and oddly enough the subject would often

remark on its inappropriation himself, e.g., in telling some story, with much giggling, he would say that it seemed absurd that it was so funny and yet laughter was irresistible.

There were two subjects out of twenty who did not complete the investigation. One subject, (#20), for personal reasons had to drop out and did not complete any testing. The other subject, (#8), was an interesting case. This subject completed the control session. He came to the second session and while he was smoking, he indicated that he was getting extremely high. He said that he "had the real stuff", (he did). He was only able to smoke 0.8 grams of the total 1.3 grams of marihuana. He complained that he was too high, and that he would likely fall asleep on us if he tried to finish all the sample off. Therefore, he was driven home by cab. The next day the same subject phoned and indicated that he would not complete the rest of the tests. He felt that he was being used as a "guinea pig" and as a result refused to come out any more.

The eighteen subjects were asked at the end of each testing session to guess whether they smoked marihuana or placebo. The subjects were not told initially whether they had smoked a marihuana or placebo sample. While this study was designed primarily to quantitate pharmacological effects on performance and deliberately avoided the intensely subjective phenomenon of the "high", certain observations do fit with prior reporting of these effects. Only three subjects concluded that they smoked marihuana when they actually

had the placebo. The rest of the subjects were able to distinguish between the marihuana and the placebo. This was likely because only one marihuana sample was smoked and it was assayed as a potent sample. If other weaker samples were also used, this may have helped mask the placebo material. Although the subjects commented that the placebo had the same physical characteristics as marihuana, (appearance, smell and taste), but they were both extremely harsh to smoke. When subjects smoked marihuana, comments such as, "I feel weightless," "I'm as high as a kite," "Boy, am I ever ripped off," and others were common though unsolicited. When the subjects were administered placebo, they experienced some degree of euphoria at first. They were also slightly dizzy. They attributed these observations to inhaling smoke and the harshness of the sample itself.

Another subjective finding which was reported after the subjects smoked marihuana was that lights appeared to be much brighter. The subjects also indicated that they did not appear to be dizzy nor did their vision appear to be blurred and no indication of slurred speech was evident. The observer did notice that the subjects' eyes were glassy in appearance and their pupils were dilated somewhat after smoking marihuana. Other studies report the lack of any change in pupil size of the subjects after they had smoked marihuana (98). This discrepancy emphasizes the need for data from carefully controlled investigations rather than from casual observation of anecdotal reports in the obser-

vation of marihuana smoking.

Other physical changes that occurred in all subjects were also of great interest and importance.

The subjects' ability to physical performance on the bicycle ergometer is related to the heart rate response at a controlled set work load (bicycle tension x average pedal revolutions per minute x 6 meters (distance of 1 complete pedal revolution)). As reported in the results, there was a marked, significant increase in the subjects' resting pulse rate and resting blood pressure (both systolic and distolic). These results indicate why there was a significant drop in the physical work capacity. The subjects were only able to perform the same work with a higher heart rate after they smoked the marihuana. The D9-THC has been reported (61) to be in the plasma of the blood. This may prevent the same amount of oxygen being transported to the working muscles at the same heart rate. As a result the heart rate and cardiac output must increase to satisfy the demands of the working muscles.

The significant increase which was reported for resting heart rate and blood pressure differs in some instances with findings from other authors. Forney (35), Volavka et al (93), Domino (31), and Isbell et al (50) reported a significant increase in pulse rate which was dose related after smoking marihuana. Weil et al (98) also reported a significant increase in pulse rate after smoking marihuana, but which was not dose related. Weil et al (98) used 4.5 mg. to 18 mg. compared to the authors

18.2 mg. of D9-THC. The other authors reported dosages per Kg. body weight but the body weights were not illustrated. Hollister (45), Manno et al (62), Le Guardia (64), and Jones (53, 54) illustrated, by administering one dose of marihuana by smoking, a significant pulse rate increase which agree with the author's findings. Manno et al (62) used 10 mg. for his study compared to the 18.2 mg. administered by the author in this study.

Isbell et al (50) reported that blood pressure remained constant after the drug was smoked which does not agree with the significant rise in blood pressure found in this study. Ames (3) and Waskow (97) reported a rise and drop respectively in blood pressure after oral administration of the drug; although their results were not statistically significant. Weil et al (98) felt that enough research was evident on blood pressure and therefore did not record blood pressure measures.

Lack of any change in muscular strength of the subjects after they had smoked marihuana is an enlightening finding especially because Hollister (4) demonstrated muscle weakness objectively with the finger ergograph. These two findings again emphasize the need for more objective data on any changes in muscle strength both grossly and at the cellular level.

No significant change was found in the subjects expired flow rate from the lungs after smoking marihuana. Although subtle changes were evident. The marihuana smoke

was inhaled into the lungs and little or no smoke escaped wither from the pipe or the subject's lungs into the atmosphere. This indicates that possibly the dead air space of the lungs along with the alveolar sacs were filled with the smoke, but no changes in flow rate occurred after the placebo or marihuana session. Therefore, the smoke goes through a chemical reaction as a result of it burning and be directly absorbed into the cardiovascular system via the alveoli.

The phenomena that no change in sensitivity threshold was evident indicates that the fine nerve endings of the somatic nervous system of the index fingers are not significantly affected as a result of smoking marihuana. Other parts of the central nervous system, (C.N.S.), may be affected but this investigation was limited to the pressure receptors of the index fingers.

The pilot simulator used in measuring complex coordination was extremely interesting and unique. Remember from the results that no significant change occurred in complex coordination between the three treatments, (control, placebo, marihuana), over the four time trials. But it is interesting to note at this time, for further investigation, that changes did occur and that the subjects did not score the same results on different trials or during each treatment session. For example, some subjects scored better after they had smoked marihuana while others scored better in the control session or after they had smoked the

placebo sample. These scores did not depend on any set order in which the sessions took place. The answer to this and many other tasks like it lies in further investigations which are more highly structure and specific.

Finally, the author would like to comment on the fact that the marihuana appeared to be a relatively high intoxicant in this study. If these results seem to differ from those of other earlier investigations, it must be remembered that other experimenters have given marihuana orally, have given doses much higher than those commonly smoked by users, have administered potent synthetics, and have not strictly controlled the laboratory setting. As noted in the review of the literature, more powerful effects are often reported by users who ingest preparations of marihuana. This may mean that some active constituents which enter the body when the drug is ingested are destroyed by combustion, a suggestion that must be investigated in man. Another consideration is the extent to which synthetic THC reproduces marihuana intoxication -- a problem that must be resolved before marihuana research proceeds with THC instead of the natural resin of the whole plant.

A few questions about marihuana are still left unanswered. What is the true potency of THC? Alkaloids may be found in the plant, but are these significantly active or present in significant quantity? Can other materials which appear inactive in the plant, actively interact with the THC cannabinoid to make it more active, or convert to other active materials within the body?

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

A sample of twenty volunteer human male marihuana smokers were used in the investigation. Each subject, age twenty-one to twenty-seven, reported to a neutral laboratory setting for three different testing sessions. Eighteen subjects completed the investigation. On the first testing session, each subject reported and completed the test battery with no drug or placebo being administered. This was used as his control test. On the second testing session, held at the same time of day, each subject smoked either marihuana or placebo before proceeding with the test battery. On the third testing session, each subject reported smoked the opposite of what he had in the previous session, before completing the test battery. The investigation was by the double blind method. Each subject smoked 1.4 grams of marihuana which contained 1.3% D⁹-THC. Therefore, 18 mgms. of pure D⁹-THC was smoked in a certain period of time. Each subject also smoked 1.4 grams of placebo which did not contain any cannabis intoxicants.

The following parameters were measured and recorded on each subject: resting heart rate, blood pressure, PWC₁₇₀, muscle strength, forced vital capacity, expired flow rate from the lungs, sensitivity threshold and muscular complex coordination.

The resting heart rate was significantly higher, (0.05 level), between the control and marihuana groups and between the placebo and marihuana group. But no significant difference occurred between the control and placebo group.

Blood pressure, both systolic and diastolic, was significantly elevated, (0.05 level), between the control and marihuana group and between the placebo and marihuana group. No significant difference was found between the control and placebo group.

PWC₁₇₀ was significantly lowered, (0.05 level), as a result of smoking marihuana. But no significant difference was found between the control and placebo groups when PWC₁₇₀ was measured.

Marihuana had no significant effect on muscle strength in the dominant or nondominant hand as measured by the hand dynamometer. Also, the smoking of marihuana showed no significant results for forced vital capacity of the lungs or the flow rate of expired air from the lungs.

The sensitivity threshold receptors located and tested in the index fingers of the dominant and nondominant hand revealed no significant difference as a result of smoking marihuana. Over a period of four time trials, no significant difference occurred with complex coordination as measured by a pilot simulator for any treatment groups after smoking marihuana.

CONCLUSIONS

As a result of this investigation, it can be stated that the smoking of marihuana affects a person's heart rate and blood pressure. We can also conclude that a person's capacity to do work on the bicycle ergometer is also lowered significantly. This would greatly affect the athlete's ability to perform up to standard on the playfield. Fatigue, as a result, may set in sooner than is expected.

On the other hand, we can conclude, as a result of the investigation, that muscle strength and muscle coordination does not change. Therefore, subjective statements by athletes that their performance is improved after smoking marihuana as far as strength and coordination are concerned is false. Their strength and coordination does not improve but in the same manner it is not reduced.

Results of this investigation also leads the author to conclude that more substantial scientific evidence and investigation into the effects of cannabis sativa on human performance is needed before any rash and hasty evidence of facts are revealed as the ultimate truth.

RECOMMENDATIONS

Scientific investigation into the effects of the cannabis sativa plant on human performance is very young. Therefore, if further studies are to develop as a result of this investigation, a few recommendations may be helpful.

1. Further investigations should look at various dosages of the active cannabinoids.

2. Various isomers of the active tetrahydrocannabinol should also be investigated in order to make available which isomers are stronger or weaker in potency.

3. Men, women, naive and chronic smokers of marijuana should be investigated for different physiological changes.

4. A long term study is needed to find out the physiological, psychological and sociological long term effects on human performance and behavior.

5. The amount of pure D^9 -THC should be strictly controlled. No more than 35 mg. should be given clinically for a 70 kg. persons (95).

6. The dosage of the active ingredient used should be measured out per kg. of body weight and not the same amount for each subject.

7. Other physiological parameters not investigated thoroughly yet, should be investigated.

8. Various methods of administration of the drug should be compared and traces of C^{14} tagged on to the active intoxicant to see how much is being metabolized and how much is being excreted in the urine and feces unchanged. Popular routes of administration are smoking, orally, and injection, (subcutaneously and interperitoneally).

9. More information is needed on the chemistry, pharmacology and biochemistry of the cannabinoids and their metabolism.

10. More work at the cellular level of investigation

is needed.

11. More human studies should be performed.

12. Interpersonal relations are more important than the setting. Therefore, groups should smoke together rather than individually in a neutral laboratory setting.

13. More grants should be made available so more sophisticated investigations can be conducted.

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APPENDIX "A"

SUBJECT PERSONAL DATA

SUBJECT NUMBER	AGE (Years)	HEIGHT (Inches)	WEIGHT (Pounds)	SMOKER		MARIHUANA HABITS PER WEEK	OCCUPATION
				YES	NO		
1	24	71.5	148.0		X	5	Musician
2	22	68.0	155.0		X	2 - 3	Unemployed
3	22	68.5	186.5		X	5 - 6	Musician
4	21	73.0	145.0	X		7	Student
5	24	70.0	153.0		X	2	Unemployed
6	23	67.5	144.5		X	2	Unemployed
7	23	75.0	186.0	X		7	Student
8	--	----	-----	-----		-----	-----
9	23	70.5	152.0		X	3 - 4	Unemployed
10	22	70.5	136.5	X		2	Student
11	24	71.0	141.5		X	2 - 3	Unemployed
12	22	70.0	137.5		X	1 - 2	Musician
13	24	68.0	141.5	X		7	Student
14	27	68.0	171.0		X	5	Artist
15	22	71.0	166.5	X		3	Student
16	22	71.5	148.0	X		5 - 6	Unemployed
17	24	71.5	164.0	X		3	Student
18	24	73.5	139.5		X	7	Student
19	24	66.0	128.0	X		35	Student
20	--	----	-----	-----		-----	-----

RESTING HEART RATE (BEATS PER MINUTE)

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	84	74	130
2	84	92	105
3	67	69	98
4	62	45	98
5	85	99	117
6	66	77	98
7	84	98	129
8	Incomplete	Incomplete	Incomplete
9	61	78	92
10	76	81	107
11	94	71	125
12	73	64	84
13	69	73	107
14	78	96	97
15	85	91	113
16	64	63	82
17	61	76	87
18	63	86	113
19	71	73	122
20	Incomplete	Incomplete	Incomplete

SYSTOLIC BLOOD PRESSURE

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	115	116	118
2	126	130	130
3	120	138	130
4	124	130	140
5	112	114	132
6	122	110	130
7	146	128	148
8	Incomplete	Incomplete	Incomplete
9	130	126	140
10	108	102	112
11	118	116	144
12	122	126	130
13	130	136	148
14	132	130	160
15	124	118	140
16	128	114	132
17	130	134	140
18	96	132	120
19	96	100	108
20	Incomplete	Incomplete	Incomplete

DIASTOLIC BLOOD PRESSURE

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	70	72	80
2	78	80	90
3	86	94	90
4	80	84	90
5	70	78	88
6	74	76	90
7	92	88	96
8	Incomplete	Incomplete	Incomplete
9	84	86	98
10	60	64	80
11	80	72	110
12	78	80	88
13	92	94	118
14	87	85	114
15	80	78	96
16	72	72	84
17	80	90	100
18	62	86	82
19	68	70	68
20	Incomplete	Incomplete	Incomplete

PWC 170 (CONTROL

SUBJECT NO.	HEART RATE			PEDAL REVS.			TENSION			WORKLOAD		
1	98	123	158	200	211	198	1.0	2.0	3.0	300	600	891
2	105	132	143	214	210	200	1.0	2.0	3.0	321	630	900
3	96	105	129	198	202	199	1.0	2.0	3.5	297	606	1044.75
4	80	120	164	196	202	210	1.0	2.0	3.0	294	606	945
5	102	105	123	192	193	204	0.5	1.0	2.0	144	289.5	612
6	97	117	150	198	199	201	1.0	2.0	3.0	297	597	904.5
7	114	132	150	196	195	197	1.0	2.0	3.0	294	585	886.5
8	Incomplete			Incomplete			Incomplete			Incomplete		
9	101	129	158	200	199	197	1.0	2.0	3.0	300	597	886.5
10	117	143	170	217	223	202	1.0	2.0	3.0	325.5	669	909
11	115	148	161	195	198	199	1.0	2.0	2.5	292.5	594	746.25
12	84	136	161	196	200	196	1.0	2.5	3.0	294	750	882
13	98	113	134	196	191	201	1.0	2.0	3.0	294	573	904.5
14	110	125	148	201	198	199	1.0	2.0	3.0	301.5	594	895.5
15	97	125	153	190	198	197	1.0	2.0	3.5	285	594	1034.25
16	94	130	155	200	199	187	1.0	2.5	3.0	300	746.25	841.5
17	107	132	164	200	198	198	1.5	2.5	3.5	450	742.5	1039.5
18	93	118	161	198	199	189	1.0	2.0	3.0	297	597	850.5
19	106	123	148	200	200	194	1.0	2.0	3.0	300	600	873
20	Incomplete			Incomplete			Incomplete			Incomplete		

PMC 170 (PLACEBO)

SUBJECT NO.	HEART RATE			PEDAL REVS.			TENSION			WORKLOAD		
1	102	132	170	200	200	198	1.0	2.0	3.0	300	600	891
2	110	138	161	206	212	203	1.0	2.0	3.0	309	636	913.5
3	88	105	136	201	200	204	1.0	2.0	3.5	301.5	600	1071
4	108	134	167	197	196	204	1.0	2.0	3.0	295.5	588	918
5	90	125	132	194	211	210	0.5	1.5	2.0	145.5	474.75	630
6	100	117	143	201	205	196	1.0	2.0	3.0	301.5	615	882
7	118	132	148	198	193	201	1.0	2.0	3.0	297	579	904.5
8	Incomplete			Incomplete			Incomplete			Incomplete		
9	103	141	173	200	200	200	1.0	2.0	3.0	300	600	900
10	113	150	173	220	219	211	1.0	2.0	3.0	330	657	949.5
11	99	118	155	200	198	201	1.0	2.0	3.0	300	594	904.5
12	110	143	155	210	195	196	1.0	2.0	3.0	315	585	882
13	102	129	164	199	198	200	1.0	2.0	3.0	298.5	594	900
14	115	129	148	200	198	198	1.0	2.0	3.0	300	594	891
15	101	120	132	197	203	200	1.0	2.0	3.0	295.5	609	900
16	97	120	161	200	190	200	1.0	2.0	3.0	300	570	900
17	105	150	170	200	198	200	1.0	2.5	3.0	300	742.5	900
18	100	122	167	200	197	200	1.0	2.0	3.0	300	591	900
19	113	130	155	200	199	198	1.0	2.0	3.0	300	597	891
20	Incomplete			Incomplete			Incomplete			Incomplete		

PWC 170 (MARIHUANA)

SUBJECT NO.	HEART RATE			PEDAL REVS.			TENSION			WORKLOAD		
1	141	158	170	200	200	195	1.0	1.5	2.0	300	450	585
2	113	150	170	204	197	201	1.0	2.0	3.0	306	591	904.5
3	105	118	143	200	198	199	1.0	2.0	3.0	300	594	895.5
4	118	161	173	198	207	207	1.0	2.0	2.5	293	621	776.25
5	113	123	150	206	210	236	0.5	1.0	2.0	154.5	315	708
6	113	143	167	198	192	204	1.0	2.0	3.0	297	576	918
7	130	153	170	200	206	200	1.0	2.0	2.5	300	618	750
8	Incomplete			Incomplete			Incomplete			Incomplete		
9	125	155	176	200	200	200	1.0	2.0	3.0	300	600	900
10	132	150	170	207	211	208	1.0	1.5	2.0	310.5	474.75	624
11	148	158	176	200	200	200	1.0	1.5	2.0	300	450	600
12	130	153	173	206	198	200	1.0	2.0	2.5	309	594	750
13	132	155	173	200	199	199	1.0	1.5	2.0	300	447.75	597
14	122	141	167	200	200	197	1.0	2.0	3.0	300	600	886.5
15	123	141	161	201	200	200	1.0	2.0	3.0	301.5	600	900
16	97	127	161	200	200	200	1.0	2.0	3.0	300	600	900
17	102	125	155	200	198	199	1.0	2.0	3.0	300	594	895.5
18	118	158	170	200	201	199	1.0	2.0	2.5	300	603	746.25
19	134	158	164	185	198	191	1.0	1.5	2.0	277.5	445.5	573
20	Incomplete			Incomplete			Incomplete			Incomplete		

PWC 170 SCORES

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	1022.60	903.16	578.29
2	1245.87	1018.90	861.11
3	1955.24	1618.72	1325.99
4	992.26	955.47	727.57
5	1593.92	1006.37	1008.17
6	1147.21	1260.84	927.91
7	1214.20	1349.21	773.05
8	Incomplete	Incomplete	Incomplete
9	1013.26	864.98	808.94
10	928.43	895.90	629.74
11	822.64	1081.64	547.27
12	978.06	990.41	736.75
13	1518.55	968.42	568.92
14	1249.73	1294.65	939.25
15	1239.92	1608.13	1047.01
16	1026.98	995.71	989.64
17	1110.53	911.47	1073.88
18	943.82	946.36	727.72
19	1186.90	1115.09	595.37
20	Incomplete	Incomplete	Incomplete

PWC₁₇₀ /Kg. BODY WEIGHT

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	15.20	13.43	8.60
2	17.68	14.46	12.22
3	23.07	19.10	15.64
4	15.05	14.50	11.04
5	22.92	14.47	14.50
6	17.47	19.20	14.13
7	14.36	15.96	09.14
8	Incomplete	Incomplete	Incomplete
9	14.67	12.52	11.71
10	14.96	14.44	10.15
11	12.79	15.84	08.51
12	15.65	15.85	11.79
13	23.61	15.06	08.85
14	16.08	16.66	12.08
15	16.38	21.25	13.83
16	15.27	14.80	14.71
17	14.90	12.23	14.40
18	14.88	14.92	11.48
19	20.40	19.17	10.23
20	Incomplete	Incomplete	Incomplete

PREDICTED MVO_2

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	3.2	2.7	1.7
2	3.2	2.8	2.5
3	3.9	3.9	3.0
4	3.1	2.7	2.1
5	2.8	2.9	2.2
6	3.4	3.4	2.5
7	3.1	3.0	2.2
8	Incomplete	Incomplete	Incomplete
9	3.0	2.6	2.4
10	2.6	2.5	1.9
11	2.4	3.9	1.8
12	3.0	2.7	2.2
13	3.7	2.9	1.8
14	3.2	3.1	2.6
15	3.8	3.8	2.7
16	3.2	3.2	3.0
17	3.3	2.7	3.1
18	3.1	3.0	2.2
19	3.3	3.0	1.8
20	Incomplete	Incomplete	Incomplete

GRIP STRENGTH (DOMINANT HAND)

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	61.50	62.00	62.50
2	58.25	57.25	55.00
3	55.50	57.00	54.75
4	61.50	56.00	54.75
5	49.50	55.75	80.50
6	58.00	54.50	51.00
7	54.50	60.00	55.25
8	Incomplete	Incomplete	Incomplete
* 9	51.50	50.75	49.25
10	44.50	51.25	50.00
11	50.00	47.50	52.50
12	40.50	44.50	45.00
13	55.00	53.50	52.00
14	51.50	52.00	51.50
15	52.50	57.00	58.00
16	53.50	54.50	53.00
17	55.50	56.25	52.00
18	58.50	55.50	54.25
19	50.00	45.00	43.75
20	Incomplete	Incomplete	Incomplete

GRIP STRENGTH (NONDOMINANT HAND)

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	52.00	49.25	46.00
2	60.25	56.50	51.25
3	56.00	49.75	51.25
4	55.00	55.50	51.00
5	53.00	52.25	47.00
6	53.00	51.00	50.00
7	59.00	52.00	49.50
8	Incomplete	Incomplete	Incomplete
* 9	49.50	54.25	43.25
10	46.50	49.50	51.75
11	49.00	50.00	50.00
12	41.00	40.75	41.00
13	51.00	52.50	50.00
14	51.00	48.00	48.00
15	53.00	55.00	52.00
16	50.50	48.50	45.50
17	57.50	55.50	51.50
18	56.00	58.50	53.00
19	44.50	43.00	41.00
20	Incomplete	Incomplete	Incomplete

EXPIROGRAPH (F.V.C. - liters)

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	5.19	5.25	4.40
2	4.68	4.49	4.61
3	6.18	6.29	6.18
4	5.38	5.45	5.38
5	----	----	----
6	4.77	4.37	4.20
7	6.25	6.52	6.01
8	Incomplete	Incomplete	Incomplete
9	----	----	----
10	----	----	----
11	5.01	5.16	5.05
12	4.55	4.49	4.41
13	4.44	5.22	4.94
14	5.06	5.11	5.19
15	5.61	4.81	5.69
16	4.61	5.22	4.29
17	5.77	5.94	5.86
18	----	----	----
19	4.29	3.68	4.41
20	Incomplete	Incomplete	Incomplete

FLOW RATE FROM 0-25% - liter/sec.

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	5.19	4.74	2.70
2	3.20	3.36	7.43
3	7.73	7.66	4.44
4	5.24	6.46	4.47
5	----	----	----
6	4.53	6.79	4.48
7	7.47	6.82	5.22
8	Incomplete	Incomplete	Incomplete
9	----	----	----
10	----	----	----
11	4.63	6.14	6.06
12	6.01	7.16	4.55
13	4.42	5.22	4.44
14	6.42	5.46	6.12
15	6.41	6.84	6.97
16	3.73	6.79	4.20
17	3.06	3.25	3.88
18	----	----	----
19	4.20	3.06	4.45
20	Incomplete	Incomplete	Incomplete

FLOW RATE FROM 25-75% - liters/sec.

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	2.27	3.11	2.98
2	4.93	5.22	4.36
3	4.90	5.01	5.77
4	4.34	4.20	4.61
5	----	----	----
6	3.11	3.49	3.32
7	4.12	4.63	3.87
8	Incomplete	Incomplete	Incomplete
9	----	----	----
10	----	----	----
11	3.28	3.54	3.62
12	4.74	4.90	4.55
13	2.96	3.28	3.35
14	4.12	4.45	4.60
15	6.41	4.84	6.97
16	4.01	4.34	4.20
17	4.81	5.74	3.73
18	----	----	----
19	3.40	2.52	3.75
20	Incomplete	Incomplete	Incomplete

SENSITIVITY THRESHOLD (DOMINANT HAND)

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	3.22	3.22	3.22
2	3.22	3.22	3.22
3	3.22	3.22	3.22
4	2.44	2.44	2.44
5	3.22	3.22	3.22
6	3.22	3.22	3.22
7	3.22	3.22	3.61
8	Incomplete	Incomplete	Incomplete
* 9	2.44	3.22	2.44
10	3.22	3.22	3.84
11	3.22	3.22	3.61
12	3.22	3.22	3.22
13	2.44	2.44	3.22
14	2.44	2.44	3.84
15	2.44	2.44	3.22
16	2.44	2.44	2.44
17	3.22	3.22	3.22
18	3.22	3.22	3.22
19	2.44	2.44	2.44
20	Incomplete	Incomplete	Incomplete

SENSITIVITY THRESHOLD (NONDOMINANT HAND)

SUBJECT NO.	CONTROL	PLACEBO	MARIHUANA
1	3.22	3.22	3.22
2	3.22	3.22	3.22
3	3.22	3.22	3.22
4	2.44	2.44	2.44
5	3.22	3.22	3.22
6	3.61	3.22	3.22
7	3.22	3.22	3.84
8	Incomplete	Incomplete	Incomplete
* 9	2.44	2.44	2.44
10	3.22	3.22	3.61
11	3.22	3.22	3.84
12	3.22	3.22	3.22
13	2.44	2.44	3.22
14	2.44	3.22	3.61
15	2.44	2.44	3.22
16	2.44	3.22	2.44
17	3.22	3.22	3.22
18	3.22	3.61	3.22
19	2.44	2.44	2.44
20	Incomplete	Incomplete	Incomplete

PILOT SIMULATOR (Complex Coordination) - CONTROL

SUBJECT NO.	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4
1	16	18	18	18
2	15	18	15	19
3	9	13	15	15
4	10	13	14	14
5	10	10	12	13
6	17	18	18	17
7	11	13	13	13
8	Incomplete	Incomplete	Incomplete	Incomplete
9	16	15	19	22
10	14	18	14	18
11	13	12	13	13
12	16	16	17	19
13	8	14	14	14
14	13	13	14	15
15	10	12	14	15
16	8	13	11	13
17	15	16	16	18
18	18	18	17	18
19	12	13	12	14
20	Incomplete	Incomplete	Incomplete	Incomplete

PILOT SIMULATOR (Complex Coordination) - PLACEBO

SUBJECT NO.	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4
1	18	25	24	27
2	16	20	21	21
3	15	18	14	17
4	15	17	15	17
5	11	15	13	14
6	18	21	20	20
7	12	15	15	15
8	Incomplete	Incomplete	Incomplete	Incomplete
9	21	22	26	27
10	16	18	15	18
11	15	19	19	19
12	21	22	22	25
13	14	14	16	14
14	21	23	19	23
15	13	16	12	18
16	14	16	17	15
17	20	24	26	23
18	17	22	19	21
19	16	17	20	21
20	Incomplete	Incomplete	Incomplete	Incomplete

PILOT SIMULATOR (Complex Coordination) - MARIHUANA

SUBJECT NO.	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4
1	12	13	17	13
2	15	22	24	22
3	17	17	12	15
4	16	22	16	20
5	11	16	17	16
6	6	14	15	12
7	6	13	11	11
8	Incomplete	Incomplete	Incomplete	Incomplete
9	18	17	26	22
10	13	20	19	14
11	12	20	17	19
12	24	24	26	28
13	11	13	17	15
14	14	12	16	17
15	7	18	17	17
16	11	15	15	11
17	15	18	21	19
18	19	20	20	18
19	11	15	13	15
20	Incomplete	Incomplete	Incomplete	Incomplete

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